Optimal continuous variable quantum teleportation with limited resources

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Given a certain amount of a quantum resource, what is the most efficient way to accomplish a practical task? We address this question in the relevant case of continuous variable quantum teleportation protocols implemented using two-mode Gaussian states with a limited degree of entanglement and energy. We first characterize the class of single-mode phase-insensitive Gaussian channels that can be simulated via a Braunstein--Kimble protocol with non-unit gain and minimum shared entanglement or steering, showing that infinite energy is not necessary apart from the special cases of the quantum limited attenuator and amplifier. We then consider the problem of teleporting single-mode coherent states with Gaussian-distributed displacement in phase space. Performing a geometrical optimization over phase-insensitive Gaussian channels, we determine the maximum average teleportation fidelity achievable with any finite entanglement and for any realistically finite variance of the input distribution. We generalize our results to secure teleportation beyond the no-cloning threshold, determining as well the maximum average teleportation fidelity for any finite steering available as a resource.

Application of Structural Physical Approximation (SPA) of Partial Transpose state in Teleportation

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We construct a witness operator to detect whether the eigenvalue of SPA of Partial Transpose state is less than 2/9 or not? Further we use SPA of Partial Transpose of an arbitrary two qubit state and then derive a new condition on the entries of two qubit density matrix, which tells us that whether the corresponding density matrix is useful for teleportation or not?

Nonlocality and Multiqubit States

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Nonlocality is one of the most intriguing phenomenon associated with quantum systems. Following Bell, we explore the nonlocality of simple pure multiqubit systems using a set of inequalities. We find that for certain measurement scenarios, a number of facet inequalities are not maximally violated by maximally entangled states. We have also constructed inequalities which do so for simple multiqubit systems.

Violation of a Leggett-Garg Inequality Exploiting Anomalous Weak Values

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The non-classicality pointed out by Leggett-Garg inequalities [1] and Bell inequalities [2] represent one of the most investigated subjects concerning foundations of quantum mechanics, both from the theoretical and experimental point of view.
Recently, a new emerging quantum measurement protocol, the weak measurements, has demonstrated to have a great potential for what concern the improvement of measurement techniques [3][4] as well as non-classicality tests [5]. A direct connection can be established between the violation of Leggett-Garg inequalities and the emergence of anomalous weak values [6][7]. Here, I show the results of an experiment aimed to violate the inequality of a four-time Legget-Garg test by mean of single and sequential weak measurements performed on heralded single photons. The violation of the Leggett-Garg inequality, observed in different experimental conditions, shows a new kind of connection between such violation and anomalous weak values [8], achieving a deeper knowledge on the link between weak values and Leggett-Garg inequalities.

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Sharing entanglement via noisy quantum channels: One-shot optimal

singlet fraction and entanglement negativity

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Entangled states, shared between physically separated observers, are critical resources for distributed quantum information processing tasks. Sharing of entanglement, however, requires sending quantum systems down quantum channels which are typically noisy. The standard protocol between two remote observers, Alice and Bob who do not share any prior correlation, is particularly simple: Alice sends half of an appropriate pure entangled state down the quantum channel to Bob, following which they may perform some trace-preserving LOCC. We consider the one-shot instance of this problem, where the goal is to establish entangled states which are optimal with respect to singlet-fraction and entanglement negativity, for every use of the quantum channel. For qubit channels, we exactly compute the optimal singlet fraction and give an explicit protocol to achieve the optimal value. The protocol distinguishes between unital and nonunital channels and requires no local post-processing. In particular, the optimal singlet-fraction is achieved using a maximally entangled state if and only if the channel is unital. Similar observations are drawn for entanglement negativity. The aforementioned results clearly demonstrate that maximally entangled states cannot be the preferred choice for entanglement sharing when the qubit channel is non-unital (e.g. amplitude damping). How well such observations hold up in higher dimensions? We show that for a family of quantum channels, in every finite dimension greater than or equal to three, one-shot optimal singlet fraction and negativity are attained only using nonmaximally entangled states. We also observe that the generalization of the one-shot optimal singlet fraction formula for qubit channels does not hold in general in higher dimensions. A consequence of our results is that the ordering of entangled states in all finite dimensions may not be preserved under trace-preserving LOCC.

Open Quantum Systems and Quantum Information in Relativistic and Sub-atomic Systems

Subhashish Banerjee
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We make use of ideas of quantum information and open quantum systems to study aspects of Unruh effect, neutrino oscillations and correlated neutral mesons. We will talk about the Unruh effect as well as correlated neutral mesons which are copiously produced at the high energy frontier experiments, for example, the Large Hadron Collider (LHC) at CERN, from the perspective of open quantum systems. It will be seen that quantum correlations in decaying systems, such as the mesons, can be nontrivially different from their stable counterparts. Further, we will discuss some aspects of neutrino oscillations from the perspective of quantum information.

Forging the culture of quantum information science

Charles Bennett
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Physicists, mathematicians and engineers, guided by what has worked well in their respective disciplines, have historically developed different scientific tastes, different notions of what constitutes an interesting, well-posed problem or an adequate solution. While this has led to some frustrating misunderstandings, it has invigorated the theory of communication and computation, enabling it to outgrow its brash beginnings with Turing, Shannon and von Neumann, and develop a coherent scientific taste of its own, adopting and domesticating ideas from thermodynamics and quantum mechanics that physicists had mistakenly thought belonged solely to their field, to better formalize the core concepts of communication and computation.

Quantum Thermal Machines with Trapped Ions

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Quantum thermal machines (QTM) are those quantum systems that convert heat into useful form of work. Specific kinds of QTMs, namely the heat engines and the refrigerators, among others have been studied in quantum regimes, using discrete strokes or continuous strokes. Heat engines take the heat from a hot bath, deliver certain amount of work, and release heat to the cold bath. In most of the proposals of QTMs it is assumed that the hot bath and the cold bath are physically separated and can be switched on or off in a controlled way, just as in the case of their classical counterpart. In quantum regime, however, the interaction between the system and the bath is never switched off. Therefore, newer strategies are required for a QTM that can be implemented in a realistic scenario, and also within the quantum framework. In this context, I will present in this talk how one can implement different strokes of an Otto engine, using a trapped ion. Using two ions, one can even build a refrigerator, which takes heat from a cold bath and with certain work on the system, releases heat into the bath. I will also brief some recent results using longer spin chains and the effect of correlations on the engine efficiency.

From Macroscopic Superpositions to Quantum Gravity

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We will start by justifying the importance of creating ever more macroscopic quantum superpositions and recap the great progress already made. I will then highlight the convenience of a method were a bonafide ancillary quantum system is coupled to a much more macroscopic system to achieve the above. In particular, I will describe how Ramsey interferometry on a spin degree of freedom can be used to create and verify such a superposition and how the scale can be enhanced by using freely propagating (untrapped) objects. Finally, we will show how two such interferometers interacting purely gravitationally can enable one to test whether gravity is fundamentally a ``quantum'' entity.

Quantum processes and correlations with no definite causal order

Cyril Branciard
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The notion of causality is deeply rooted in our understanding of the world we live in: we typically understand the relationship between events in terms of causal relations, where some earlier events are causes for later events. Now, we know that the quantum world is full of weird phenomena.Cats can be in indefinite states, in a quantum superposition of being alive and dead. It has been realised recently that causal relations themselves can be indefinite, in some kind of quantum superposition. However, a good understanding of quantum processes with indefinite causal order, and of the correlations they may generate is still missing. In this talk I will describe recent research on those new concepts, with a special focus on the subtleties that arise in the multipartite case.

Multi-partite entanglement speeds up quantum key distribution in networks

M. Epping, H. Kampermann, C. Macchiavello, and **D. Bruss**

The laws of quantum mechanics allow for the distribution of a secret random key between two parties. Here we analyse the security of a protocol for establishing a common secret key between N parties (i.e. a conference key), using resource states with genuine N-partite entanglement. We compare this protocol to conference key distribution via bipartite entanglement, regarding the required resources, achievable secret key rates and threshold qubit error rates.
Furthermore we discuss quantum networks with bottlenecks for which our multipartite entanglement-based protocol can benefit from network coding, while the bipartite protocol cannot. It is shown how this advantage leads to a higher secret key rate.

Entangling power of accelerated quantum walks

C.M. Chandrashekar
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Quantum walks has played an important role in development of quantum algorithms and quantum simulations. It is is also shown to implement the set of universal gates and thus are quantum computational primitives. In this talk I will present a scheme to describe accelerating discrete-time quantum walk. Using the scheme, we show the effect of acceleration on the entanglement between the two walkers from different frame of references. With this we will discuss the behaviour of entanglement in relativistic quantum walks and use it to simulate few interesting dynamics in relativistic quantum mechanics and quantum field theory.

Finite time corrections to the efficiencies of heat engines based on quantum Brownian oscillator

Subhas Chaturvedi
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We present a stochastic thermodynamic framework for computing the efficiencies for heat engines modelled after a quantum Brownian oscillator. Making essential use of the Wigner phase space description. The framework thus developed not only permits one to make contact with the traditional thermodynamics but allows one to go beyond it by allowing us to compute finite time corrections to the efficiencies and to derive thermodynamic complementarity relations and work fluctuations. The case of the Carnot engine is discussed in some detail.

Coherence, Quantum Fisher Information, Superradiance and Entanglement are Interconvertible Resources

K.C. Tan, S. Choi, H. Kwon, H. Jeong

Abstract: We discuss the relationship between quantum Fisher information, superradiance and entanglement through the lens of coherence. First, we demonstrate how quantum Fisher information and superradiance can be formulated as coherence measures in accordance with the resource theory of coherence, thus establishing a direct link between metrological information, superradiance and coherence. The arguments are then generalized to show that coherence may be considered as the underlying fundamental resource for any functional of state that is first of all faithful, and second of all concave or linear, which allows us to simplify the process of discovering and proving new coherence measures. Arguments are then presented that show quantum Fisher information and the superradiant quantity are in fact antithetical resources in the sense that if coherence were directed to saturate one quantity, then it must come at the expense of the other, which suggests that coherence may be directed towards one problem or the other, but not simultaneously. Finally, we will show that coherence, quantum Fisher information, superradiant quantity, and entanglement are mutually interconvertible resources under incoherent operations.

Quantumness from ultrafast spectroscopy experiments

Animesh Datta, George Knee, Max Marcus, Luke Smith

The role of quantumness in the energy transfer process in light-harvesting complexes has long been debated. A major obstacle in verifying competing hypothesis is the complicated nature of ultrafast spectroscopy experiments. While multidimensional ultrafast optical spectroscopy has been crucial in clarifying the nature of interacting multi-chromophoric systems, the underlying mechanisms of energy transport in light-harvesting complexes remain unclear. Earlier works have shown that 2D electronic spectroscopy can provide enough information to perform quantum process tomography on the multi-chromophoric light-harvesting complexes. We build upon this methodology to provide more efficient spectroscopic techniques that can provide bounds of measures of quantumness. In particular, we show how the nature of quantum correlations can be extracted directly from measured data rather than hypothesized models. We expect our tools to be applicable to the evaluation of quantumness from other spectroscopy experiments or any other data stream in general.

Frozen quantum correlations

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Characterizing correlations between different subsystems of a composite quantum system has been an important field of research in quantum information. This is due to the fact that quantum correlations, in the form of entanglement, is shown to be significantly more useful for performing communication and computational tasks over their classical counterparts. A main obstacle encountered in realizations of quantum information protocols is the rapid decay of quantum correlations with time in multiparty quantum systems exposed to environments. I will present scenarios involving physical systems that are realizable in the laboratory, and a specific model of environment, in which entanglement of the system, even when exposed to the environment, remains constant for a finite interval of time at the beginning of the dynamics. We call this phenomena as freezing of entanglement. I will also discuss necessary and sufficient conditions for freezing of other quantum correlation measures, when a two-qubit state with magnetization is subjected to local depolarizing channels.

Pairwise correlation inequalities and joint measurability

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We construct chained N term sequential correlation inequality based on the positivity of a sequence of moment matrices involving sequential pairwise correlations of dichotomic observables. This inequality gets violated only when incompatible sequential fuzzy POVMs are employed. However, measurement incompatibility of the POVMs employed is seen to be only necessary, but not sufficient, in general, for the violation of the inequality.
On the other hand, we point out that there exists an one-to-one equivalence between the joint measurability and the optimal violation of a steering inequality, proposed by Jones and Wiseman (Phys. Rev. A, *84*, 012110 (2011)). We propose a local analogue of this steering inequality in a single system, establishing that measurement incompatibility of the POVMs employed in the sequential measurement scheme is necessary and sufficient for the violation of the inequality.

Non-negativity of conditional von Neumann entropy and global unitary operations

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Conditional von Neumann entropy is an intriguing concept in quantum information theory. In this presentation, we examine the effect of global unitary operations on the conditional entropy of the system. We start with the set containing states with non-negative conditional entropy and find that some states preserve the non-negativity under unitary operations on the composite system. We call this class of states as Absolute Conditional von Neumann entropy Non Negative class (ACVENN). We are able to characterize such states for 2 x 2 dimensional systems, and find that it is convex and compact. On a different perspective the characterization accentuates the detection of states whose conditional entropy becomes negative after the global unitary action. This feature enables the existence of hermitian witness operators which can distinguish the unknown states which will have negative conditional entropy after the global unitary operation. We also show that this has immediate application in super dense coding and state merging as negativity of conditional entropy plays a key role in both these information processing tasks. Furthermore the relations of these class of states with absolutely separable (AS) and absolutely Bell-CHSH local (AL) states are also probed.
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Quantum heat engine using energy quantization in potential barrier

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The apparent violation of second law demonstrated with quantum Szilard engine [1] and its solution has thrown a subtle connection between information and thermodynamics [2]. In the quantum model of Szilard engine, the energy quantization plays a crucial role during insertion and removal of the barrier during the heat cycle [3,4]. In this work, this issue is addressed for different circumstances such as sudden removal and insertion of a barrier. Further, we studied quantum Stirling cycle which may not have a classical analogue. The dependence of the efficiency of the engine on length of the potential well is also studied. The possible physical realization of this engine is also discussed.

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An almost convincing scheme for discriminating the preparation basis of quantum ensemble and why it will not work

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Mixed states of a quantum system, represented by density operators, can be decomposed as a statistical mixture of pure states in a number of ways where each decomposition can be viewed as a different preparation recipe. However, the fact that the density matrix contains full information about the ensemble makes it impossible to estimate the preparation basis for the quantum system. Here we present a measurement scheme to (seemingly) improve the performance of unsharp measurements. We argue that in some situations this scheme is capable of providing statistics from a single copy of the quantum system, thus making it possible to perform state tomography from a single copy. One of the byproducts of the scheme is a way to distinguish between different preparation methods used to prepare the state of the quantum system. However, our numerical simulations disagree with our intuitive predictions. We show that a counter-intuitive property of a biased classical random walk is responsible for the proposed mechanism not working.

Fundamental Phenomena in Quantum Mechanics studied with Matter-Wave Optical Setups
--- Quantum Cheshire-Cat and Revised Uncertainty Relations ---

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The validity of quantum-mechanical predictions has been confirmed with a high degree of accuracy in a wide range of experiments. Although the statistics of the outcomes of a measuring apparatus have been studied intensively, little has been explored and is known regarding the accessibility of quantum dynamics and the evolutions of a quantum system during measurements. For this sort of fundamental studies of quantum mechanics, interferometric and polaimetric approaches, in particular by the use of neutron's matter-waves, provide almost ideal experimental circumstances. The former device explicitly exhibits quantum interference between spatially separated beams in a macroscopic scale. In contrast, interference effects between two spin eingenstates are exposed in the latter apparatus. Exploiting both strategies, alternative theories of quantum mechanics, Kochen-Specker theorem and so on have been investigated. Recently, as a study of quantum dynamics, neutron interferometer experiments are carried out: a new counter-intuitive phenomenon, called quantum Cheshire-cat, is observed. Moreover, extending the first experimental test of the new error-disturbance uncertainty relation by using a modified neutron polarimeter setup, we performed experiments investigating the validity of an advanced uncertainty relation for mixed ensemble as well as a new noise-disturbance uncertainty relation in an entropic form. In my talk, I am going to give an overview and present actual consequences of neutron optical experiments to investigations of fundamental aspect of quantum mechanics.

Probing Quantum Mechanics in the Macroregime using Marorealist inequality

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The talk would begin by providing an overall perspective and motivation for the various necessary conditions proposed for the testing of the notion of macrorealism MR (defined by the conjunction of the assumptions of realism and noninvasive measurability), viz. the Leggett-Garg inequality (LGI), Wigner's form of the Leggett-Garg inequality (WLGI), and the condition of No-Signalling in Time (NSIT). Then the talk would analyse the import of the results of the following two recent studies: (a) For multilevel spin systems, using the different necessary conditions of MR, it is shown that classicality in the sense of satisfying MR does *not* emerge in the asymptotic limit of spin, i.e. Quantum Mechanical (QM) violation of MR persists whatever be the unsharpness or coarse-grainedness of measurements. (b) The QM violation of MR in the context of a linear harmonic oscillator is invoked to reveal non-classicality of the state which is considered the most "classical-like" of all quantum states, namely the Schrödinger coherent state. In the *macrolimit*, the extent to which such nonclassicality persists for large values of mass and classical amplitudes of oscillation is quantitatively investigated, proposing a feasible experimental setup using optically levitated nano-objects.

Efficient measurement of high-dimensional quantum states

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High-dimensional quantum information protocols are extremely important as they provide several unique advantages compared to the traditional two-dimensional protocols based on the polarization of photons. This talk will present our recent experimental and theoretical work on developing efficient techniques for measuring the high-dimensional classical and quantum states of light.

Efficiency at optimal performance in quantum and mesoscopic heat engines with prior information

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Carnot efficiency, $1-T_2/T_1$, is the upper bound for all heat engines operating between two heat reservoirs at temperatures T_1 and T_2. For many models of irreversible heat engines, for instance, finite-time models, stochastic engines, quantum and mesoscopic engines, models with finite reservoirs, the efficiency at maximum power or maximum work, is closely approximated by the expression: $1 - \sqrt{T_2/T_1}$, which is also popularly known as Curzon-Ahlborn (CA) efficiency. In this talk, I shall discuss optimal performance in a class of quantum and mesoscopic heat engines, assuming a limited information of their internal energy scales. An average measure for power and work is defined based on the prior probability distribution over the uncertain parameter. It is shown that the estimation yields CA-efficiency as the efficiency at maximum power or work, with the use of Jeffreys prior, and in a specific limit of the range of prior distribution. Results are compared with use of a uniform prior. The analysis provides a new derivation of CA-efficiency which is commonly derived from an exact optimization procedure.

Nonclassicalities in multiphoton correlations

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Interference effects play a crucial role in all phenomena based on waves propagation, whose study has been of paramount importance. Interference by particles is at the heart of quantum mechanics. Focussing on photonic interferometry, which will be the principal subject of this investigation, interferometers detect how the measured light intensity changes in space or time, due to the interference of different electromagnetic fields. A change in perspective came with the interferometer invented by Hanbury-Brown and Twiss. Differently from other interferometers, the interference is based on the correlation between the intensities of electromagnetic fields. The intensity correlation function also sets criteria to characterise nonclassicalities. There have been a large number of studies on nonclassicalities based on the intensity correlations such as the Hong-Ou-Mandel interferometer. Most of the earlier studies are based on the interference between two nonclassical fields. With the technical advances we are now able to test nonclassicalities of interferences between more than two fields. In this presentation, we study the nonclassical criteria for multiphoton interference. It is crucial to understand the boundaries between what classical interference can achieve and what can be obtained only with a full quantum mechanical description. If there is any difference between the two predictions, that can be used to characterise the quantum nature of the interference. While a lot of work has already been done for a simple case of two-mode interference, the multi-mode case has not been fully explored yet. We derive bounds for classical models of light fields in this more general scenario and show that non-classical light fields can violate this bound. Such the nonclassical witness is able to detect the presence of sources with sub-Poissonian photon-number statistics, excluding the possibility of classical stochastic processes underlying them. We show that the nonclassical region is getting smaller with the increasing number of photonics modes involved in the interferometry. We also show the sign of nonclassicalities in a three-photon interference.

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Lessons from a 3-qubit experiment: from entanglement and thermalization to exact solutions.

Shruti Dogra, Vaibhav Madhok, **Arul Lakshminarayan**

A recent state-of-the-art 3-qubit transmon based experiment implementing a quantum kicked top claimed evidence of thermalization in small closed quantum systems. We demonstrate that the implemented Floquet operator is exactly solvable and analyze various quantum correlation measures comparing them with theory and experiment. Apart from a curious step-like phenomena where quantum correlations are produced every other time step, it is seen that the thermalization is strongly affected by decoherence. We also point out that the Hamiltonian can

be considered to belong to an integrable family, thus touching on the need of non-integrability for thermalization.

Optimal quantum preparation contextuality in *n*-bit parity-oblivious multiplexing task

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In [1], Spekkens *et al.* have shown that the quantum preparation contextuality [2] can power the parity-oblivious multiplexing (POM) task - a one-way communication protocol. The optimal success probability of POM task performed with the classical resources is shown to be the *same* as obtained from any preparation noncontextual theory. For the 2-bit POM task they have achieved the optimal success probability in quantum theory, violating the bound imposed by noncontextual theory. However, for 3-bit case Spekkens *et al.* provided the quantum advantage over the noncontextual POM task but optimality of it was left as an open question which we proved through the optimal quantum violation of the elegant Bell's inequality [3]. We further generalized the POM task for *n*-bit and derived the optimal quantum success probability through the optimal quantum violation of a curious form of Bell's inequality. We discuss how the degree of quantum preparation contextuality fixes the success probability of the POM task.

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The effect of entanglement and correlations on tripartite two level dipole coupled atoms.

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We consider the radiation emanating from a system of dipole coupled three two level entangled atoms. In the far field limit, the intensity characteristic of the system varies with change in angle between axis of atoms and the detector. We further investigate that the intensity pattern changes with change in spacing of atoms and the wavelength emitted radiation, where the interparticle entanglement plays a significant role in determining these properties. We also show that the intensity-intensity correlation exhibits the anti-bunching of bosons due to entanglement. Bosons, here, reveal the fermionic characteristics.

Trace distance measure of coherence

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In this talk I shall consider the ℓ_p and Schatten-p-norm based distances for possible monotones in coherence theory with incoherent operations as free operations. First, I'll show that neither is a monotone (and hence not strong monotone) for any p larger than 1. This leaves only the trace distance and C_{ℓ_1} as possible candidates. While both are monotone, the latter is a strong monotone and the former is so only for some special inputs, e.g. qubits and so called X states. Similar results for entanglement theory shall also be mentioned, in particular that C_tr is a computable quantity (formulated as SDP). Finally, I shall give an operational interpretation of C_{ℓ_1}.
Joint works with: Swapan Rana, Maciej Lewenstein and Andreas Winter
References: Phys. Rev. A 93, 012110 (2016), Phys. Rev. A 96, 052336 (2017).

Quantum trajectories for measurement of entangled states

Apoorva Patel
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Quantum correlations can be described using real stochastic variables, e.g. Wigner functions, provided that the variables can take negative values. Recently, quantum trajectories obeying nonlinear stochastic evolution have been observed during weak measurements of superconducting transmon qubits. How quantum correlations are encoded in the trajectory weights will be illustrated, using weak measurements of the Bell state as an example.

Quantum communication: The requirement, essential resources, new protocols and the effect of noise on them

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In this work, we briefly review our recent works on various aspects of quantum communication. To begin with, we will investigate the security provided by Indian banks, and show that they often failed to follow classical standards. The result of the analysis will lead to a discussion on whether the implementation of quantum cryptography can improve the situation, specially in a noisy environment. Truly quantum resources required for quantum communication will be listed from the foundational perspective and a set of systems that can be used to produce the required quantum characteristics will be mentioned. Finally, performance of insecure [1–4] and secure [1, 5–10] quantum communication schemes over various Markovian [1–8] and non-Markovian [9] noise models will be discussed.

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Preparation Uncertainty Relations Beyond Heisenberg's

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Heisenberg-Robertson's uncertainty relation expresses a limitation in the possible preparations of the system by giving a lower bound to the product of the variances of two observables in terms of their commutator. However, it does not capture the concept of incompatible observables because it can be trivial, i.e., the lower bound can be null even for two non-compatible observables. First, two stronger uncertainty relations, relating to the sum of variances, will be presented whose lower bound is guaranteed to be nontrivial whenever the two observables are incompatible on the state of the system. Second, new type of novel state-dependent uncertainty relations for product as well the sum of variances of two incompatible observables will be discussed. These uncertainty relations are shown to be tighter than the Roberson-Schrodinger uncertainty relation. Our results show that quantum world is more uncertain than what we used to think.

Device-independent self-test of true multipartite entanglement

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Quantum theory allows systems to be entangled with each other, which results in stronger than classical correlations. Most features of bipartite entangled correlations are well understood, whereas for the multipartite entanglement this is still not the case. The rich structure of the multipartite entanglement, specially the genuine multipartite entanglement, can be used for various tasks such as secure quantum cryptography & communication, quantum computation and quantum simulation, etc. In this regard, we have proposed a device-independent self-test for a class of multipartite entangled correlations based on generalized Hardy type argument. Our Hardy type test consist a set of conditions on joint probabilities which can be resolved only by a true multipartite entangled state for a given set of local observable pairs.

Structure of Incoherent Channels

Swapan Rana
Alexander Streltsov, Paul Boes, Jens Eisert

I shall talk about the structure of (strictly) incoherent operations, namely their Kraus decomposition. Various bounds on the number of Kraus operators will be given, which in general, may not be optimal. For the qubit (strictly) incoherent channels however, I shall present the optimal decomposition. Importance of this optimal decomposition (e.g. to quantum thermodynamics) will also be mentioned.

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Rigorous Quantum Limits on Monitoring Free Masses and Harmonic Oscillators

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Accurate monitoring of the position of a free mass or of a harmonic oscillator including uantum effects is very important for gravitational wave detection. There are heuristic arguments proposing that the accuracy of position monitoring is limited by the standard quantum limit (SQL) on the variance of the position operator $X(t)$:\begin{eqnarray} &\sigma^2 (X(t)) \geq \sigma^2 (X(0)) +(t^2/m^2) \sigma^2 (P(0)) \nonumber\\&\geq 2(t/m)\sigma(X(0))\sigma (P(0)) \geq \hbar t/m, \end{eqnarray}[See e.g. C. M. Caves, K. S. Thorne, R. W. P. Drever, V. D.

Sandberg, and M. Zimmermann, Rev. Mod. Phys. {\bf 52},341(1980)].Here $\sigma^2(X(t))$ and $\sigma^2(P(t))$ are the variances of the Heisenberg position and momentum operators at time t .In a seminal paper, Yuen (H. P. Yuen, Phys. Rev. Letters {\bf 51}, 719 (1983)) noted that there are contractive states for which this result is incorrect. For a harmonic oscillator of mass m and frequency ω, I derive the rigorousquantum limits (RQL), \begin{eqnarray} |\sigma^2(X(t)) -\sigma^2(X(0)) \cos ^2(\omega t)- \sigma^2(P(0))\sin ^2(\omegat)/(m\omega)^2 | \nonumber\\ \leq |\sin (2\omega t)/(2m \omega)|\sqrt{4 \sigma^2(X(0))\sigma^2(P(0)) -\hbar^2},\nonumber\end{eqnarray}and the `maximally contractive' and `maximally expanding' states which saturate them. The corresponding RQL for a free mass also follow from these bounds by taking the limit $\omega \rightarrow 0$ .The bounds and extremal contractive states for the oscillator and for a free mass enable quantum monitoring with accuracies beating the standard quantum limit. The Contractive states for oscillators improveon the Schr\"odinger coherent states of constant variance.

Multipartite entangled states can almost never be manipulated by LOCC

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Local operations assisted by classical communication (LOCC) constitute the free operations in entanglement theory. The determination of LOCC transformations is therefore crucial to understand entanglement. We characterize almost all LOCC transformations among pure states of n > 3 d?level systems with d > 2. This generalizes the findings of G. Gour, B. Kraus, N. R. Wallach, J. Math. Phys. 58, 092204 (2017), where n?qubit states were considered. We show that non-trivial LOCC transformations among generic fully entangled pure states are almost never possible. Hence, almost all multipartite states are isolated. They can neither be deterministically obtained from local unitary (LU)-inequivalent states via local operations, nor can they be deterministically transformed to pure fully entangled LU-inequivalent states. In order to derive this result we prove a more general statement, namely that generically a state has no non? trivial local symmetry. We show that these results also hold for certain tripartite systems.

n-Particle Quantum Statistics on Graphs

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We develop a full characterization of abelian quantum statistics on graphs. We explain how the number of anyon phases is related to connectivity. For 2-connected graphs the independence of quantum statistics with respect to the number of particles is proven. For non-planar 3-connected graphs we identify bosons and fermions as the only possible statistics, whereas for planar 3-connected graphs we show that one anyon phase exists. Our approach also yields an alternative proof of the structure theorem for the first homology group of n-particle graph configuration spaces. Finally, we determine the topological gauge potentials for 2-connected graphs. This is a joint work with J. Harrison, J. Keating and J. Robbins.

Quantum nonlocality from the perspective of Algorithmic Information Theory

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Algorithmic Information Theory (AIT) is an established subfield of theoretical computer science that emerged from the combination of Turing's computability theory and Shannon's information theory. In the recent years, the interplay between AIT and the theory of Bell nonlocality has lead to a number of surprising results, going from undecidable aspects of the set of quantum correlations to lower bounds on the degree of algorithmic randomness present in Bell experiments. In this talk, after a brief introduction to AIT, I will survey these results and discuss future lines of research.

NonClassical Correlations in Open Quantum Dynamics

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Open quantum dynamics in a tripartite scenario including a system, its environment and a passive reference is shown to resolve several open questions regarding not completely positive (NCP) dynamical maps as valid descriptions of open quantum evolution. The steering states of the system of interest and its environment with respect to the reference, reduced down to a dense, compact set of states of the system alone, provides a well-defined domain of action for a bonafide dynamical map describing the open evolution of the system. The map is not restricted to being completely positive (CP) but it preserves the positivity of all states in its domain. NCP open dynamics corresponding to different initial configurations of the tripartite system are explored.

Observing and tuning the effect of Feynman paths in a classical regime

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The Feynman Path Integral formalism has long been used for calculations of probability amplitudes. Over the last few years, it has been extensively used to theoretically demonstrate that the usual application of the superposition principle in slit based interference experiments is often incorrect. This has caveat in both optics and quantum mechanics where it is often naively assumed that the boundary condition represented by slits opened individually is same as them

being opened together. The correction term comes from exotic sub leading terms in the Path Integral which can be described by what are popularly called non-classical paths[1, 2]. In this talk, we will report an experiment where we have a controllable parameter that can be varied in its contribution such that the e_ect due to these non-classical paths can be increased or diminished at will [3]. Thus, the reality of these non-classical paths is brought forth in a classical experiment using microwaves, thereby proving that the boundary condition effect being investigated transcends the classical-quantum divide. We report the first measurement of a deviation (as big as 6%) from the superposition principle in the microwave domain using antennas as sources and detectors of the electromagnetic waves. Measuring a non-zero Sorkin parameter not only gives experimental veri_cation to the theoretical predictions about the deviation from the superposition principle in interference experiments, it also exemplifies an experimental scenario in which non zero Sorkin parameter need not necessarily imply falsi_cation of Born rule for probabilities in quantum mechanics which has been the basis for several experiments in recent years [4].We also show that our results can have potential applications in astronomy.

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Maximally nonlocal subspaces

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A nonlocal subspace N is a subspace of the Hilbert space H of a multi-particle system such that any element in N violates a given Bell inequality B. Subspace N is maximally nonlocal if its elements violate B to the algebraic maximum. We propose various ways by which states with a stabilizer structure can be used to construct maximally nonlocal subspaces, essentially as the degenerate eigenspaces of Bell operators derived from the stabilizer generators. Applications to the nonlocality of graph states and quantum error correcting codes, and to quantum secret sharing, are given.

Entanglement and coherence in distributed quantum networks

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Understanding the resource consumption in distributed scenarios is one of the main goals of quantum information theory. A prominent example for such a scenario is the task of quantum state merging where two parties aim to merge their parts of a tripartite quantum state. In standard quantum state merging, entanglement is considered as an expensive resource, while local quantum operations can be performed at no additional cost. However, recent developments show that some local operations could be more expensive than others: it is reasonable to distinguish between local incoherent operations and local operations which can create coherence. This idea leads us to the task of incoherent quantum state merging, where one of the parties has free access to local incoherent operations only. In this case the resources of the process are quantified by pairs of entanglement and coherence. Here, we develop tools for studying this process, and apply them to several relevant scenarios. While quantum state merging can lead to a gain of entanglement, our results imply that no merging procedure can gain entanglement and coherence at the same time. We also provide a general lower bound on the entanglement-coherence sum, and show that the bound is tight for all pure states. Our results also lead to an incoherent version of Schumacher compression: in this case the compression rate is equal to the von Neumann entropy of the diagonal elements of the corresponding quantum state. We further review the role of coherence and entanglement for other quantum technological tasks, such as quantum state conversion and assisted coherence distillation.