Book of abstracts

Q-TURN 2020

Monday 23rd November

Session: S1 Sensing and metrology *

Welcome

First of 3 live welcomes.

Kasturi Saha (invited)

A quantum diamond microscope for mapping magnetic fields

Tremendous research activity worldwide has focused on attempting to harness the exotic properties of quantum physics for new applications in metrology, computation, and communications - a push to develop "engineered quantum systems". Color centers in diamonds such as nitrogen-vacancy centers (NV centers) could provide a platform for precision magnetometry allowing for nanoscale magnetic resonance imaging (MRI) of individual complex molecules. In this talk, I will give an overview of our research towards development of imaging tools mapping neuronal signals from mammalian brain cells.

K. S. Akhilesh

Spin Squeezing in symmetric multiqubit states with two non-orthogonal spinors

Squeezed spin states are a class of permutation symmetric N particle entangled states, which exhibit re- duced quantum fluctuation in their collective spin angular momentum in a certain direction, and they are useful for quantum enhanced metrology. In this work, the celebrated Majorana representation is exploited to investigate spin squeezing in different classes of pure symmetric states of N qubits with two distinct spinors, namely the Dicke-class of states {D, N, −k, k }. It is shown that the states in the Dicke-class, characterized by two-distinct non-orthogonal spinors, exhibit spin squeezing. On obtaining a general expression for spin squeezing parameter, the variation of squeezing for different configurations is studied in detail.

Simone Felicetti

Critical Quantum Metrology with a Finite-Component Quantum Phase Transition

Quantum critical systems in proximity of phase transitions exhibit a divergent susceptibility, suggesting that an arbitrarily high precision may be achieved when they are used as probes to estimate a physical parameter. However, such an improvement in sensitivity is counterbalanced by the critical slowing down, which implies an inevitable growth of the protocol duration. Here, we design metrological protocols based on a novel kind of phase transitions observable in finite-component quantum optical systems. We show that, in spite of the critical slowing down, critical quantum optical probes can achieve a quantum-enhanced time scaling of the sensitivity in frequency-estimation protocols.

Coffee break

Martí Perarnau-Llobet

Weakly invasive metrology: quantum advantage and physical implementations

We consider the estimation of a Hamiltonian parameter of a set of highly photosensitive samples, which are damaged after a few photons N_{abs} are absorbed. The samples are modelled as a two mode photonic system, where photons simultaneously acquire information on the unknown parameter and are absorbed at a fixed rate. We show that arbitrarily intense coherent states can obtain information at a rate that scales at most linearly with N_{abs}, whereas quantum states with finite intensity can overcome this bound. The quantum advantage scales like N/N_{abs} (where N is the number of photons in the quantum state), so that few-photon entangled states can already surpass the classical bound when N_{abs} is small. We discuss an implementation in cavity QED, where Fock states are both prepared and measured by coupling atomic ensembles to the cavities.

Johannes Jakob Meyer

A variational toolbox for quantum multi-parameter estimation

We propose a variational quantum algorithm feasible on NISQ devices that can address a challenge central to the field of quantum metrology: The identification of near-optimal probes and measurement operators for noisy multi-parameter estimation problems. Our framework is applicable to both discrete and continuous variable settings on different physical platforms. We demonstrate the practical functioning of the approach through numerical simulations, showcasing how tailored probes and measurements improve over standard methods in the noisy regime. In our approach, we advocate the mindset of quantum-aided design, exploiting quantum technology to learn close to optimal, experimentally feasible quantum metrology protocols.

Alejandro Gaita Ariño

Quantum coherent spin-electric control in molecular nanomagnets

A small but interdisciplinary community works on fundamental progress towards molecular spin qubits, an effort that overlaps with the research of molecular nanomagnets. In this talk on recent results of the quantum (coherent) electric control of the spin state of molecular nanomagnets I will also aim to give an answer to "why bother with molecules as quantum hardware?" as well as a brief but critical perspective into the present status of molecular spin qubits research, including some of the achievements, intrinsic potential and intrinsic difficulties of our approach.

Meet & Greet on Remo

Session: S2 Quantum computation, simulation, machine learning and quantum error correction

Welcome

Giulia Ferrini (invited)

Resources for continuous-variable quantum computation: theory and experimental proposals

Continuous-Variable (CV) quantum computation is emerging as a promising alternative to quantum computation with two-level systems. In this approach, typical observables have a continuous spectrum, such as the real and imaginary part of the quantised electromagnetic field. In this context, specific resources (in terms of quantum states and quantum gates) have been known for decades to be resourceful, i.e. to promote the set of classically efficiently simulatable operations to universal quantum computation. This is the case of the so-called cubic phase state, as well as of the cubic phase gate. So far, efforts for implementing experimentally these resourceful elements have been undertaken in quantum optics, however it has not been possible yet to achieve them. I will present two proposals for achieving the generation of the cubic phase state as well as the implementation of a cubic phase gate with microwave technology. Availability of these elements opens for the quest of CV-NISQs - small CV quantum processors without quantum error correction, where a limited number of operations - yet beyond the domain of the classical simulatable ones - are at disposal.

Laura García-Álvarez

Efficient simulatability of Continuous-Variable circuits with large Wigner negativity

Wigner negativity is known to be a necessary resource for computational advantage in several quantum-computing architectures, including those based on continuous variables (CVs). However, it is not a sufficient resource, and it is an open question under which conditions CV circuits displaying Wigner negativity offer the potential for quantum advantage. In this work, we identify large families of circuits that display large Wigner negativity, and yet are classically efficiently simulatable, although they were not recognized as such by previously available theorems.

Martin Bohmann

Phase-space inequalities: theory and experiment

We introduce the concept of phase-space-inequality conditions for the verification of nonclassicality. This approach allows us to reveal quantum correlations even if the corresponding phase-space distributions are nonnegative. A fundamental relation between these inequality conditions and correlations measurements is given. The strength of the method is demonstrated by certifying quantum correlations from experimental data where other methods fail to do so.

Coffee break

Jeremy Adcock

Mapping graph states under local complementation

Graph states, and the entanglement they possess, are central to modern quantum computing and communications architectures. Local complementation—the graph operation that links all local-Clifford equivalent graph states—allows us to classify all stabiliser states by their entanglement. Here, we study the structure of the orbits generated by local complementation, mapping them up to 9 qubits and revealing a rich hidden structure. We provide programs to compute these orbits, along with our data for each of the 587 orbits up to 9 qubits and a means to visualise them. We find direct links between the connectivity of certain orbits with the entanglement properties of their component graph states. Furthermore, we observe the correlations between graph-theoretical orbit properties, such as diameter and colourability, with Schmidt measure and preparation complexity and suggest potential applications. It is well known that graph theory and quantum entanglement have strong interplay—our exploration deepens this relationship, providing new tools with which to probe the nature of entanglement.

Dominik Leichtle

Security Limitations of Classical-Client Delegated Quantum Computing

Secure delegated quantum computing allows a computationally weak client to outsource an arbitrary quantum computation to an untrusted quantum server in a privacy-preserving manner. One of the promising candidates to achieve classical delegation of quantum computation is classical-client remote state preparation (RSP_{CC}), where a client remotely prepares a quantum state using a classical channel. However, the privacy loss incurred by employing RSP_{CC} as a sub-module is unclear. In this work, we investigate this question using the Constructive Cryptography framework by Maurer and Renner. We first identify the goal of RSP_{CC} as the construction of ideal RSP resources from classical channels and then reveal the security limitations of using RSP_{CC}. First, we uncover a fundamental relationship between constructing ideal RSP resources (from classical channels) and the task of cloning quantum states. Any classically constructed ideal RSP resource must leak to the server the full classical description (possibly in an encoded form) of the generated quantum state, even if we target computational security only. As a consequence, we find that the realization of common RSP resources, without weakening their guarantees drastically, is impossible due to the no-cloning theorem. Second, the above result does not rule out that a specific RSP_{CC} protocol can replace the quantum channel at least in some contexts, such as the Universal Blind Quantum Computing (UBQC) protocol of Broadbent et al.. However, we show that the resulting UBQC protocol cannot maintain its proven composable security as soon as RSP_{CC} is used as a subroutine. Third, we show that replacing the quantum channel of the above UBQC protocol by the RSP_{CC} protocol QFactory, of Cojocaru et al., preserves the weaker, game-based, security of UBQC.

Miriam Backens

There and back again: A circuit extraction tale

Translations between the quantum circuit model and the measurement-based one-way model are useful for verification and optimisation of quantum computations. By expressing both one-way computations and circuits in the common language of the ZX-calculus, we give the first algorithm that can translate any one-way computation with extended gflow, i.e. allowing measurements in the XY, XZ, and YZ-planes of the Bloch sphere, into an ancilla-free circuit. Circuits can be optimised by translating them into a one-way computation, optimising this, and translating back.

Meet & Greet on Remo

Session: S3 Experiment

Welcome

Christian Schmiegelow (invited)

Using structured light to explore and exploit the quantum

I will present results on the interaction of single trapped ions with structure light beams and discuss future applications to metrology and quantum thermodynamics. Structure light can be used to tailor its action on atoms. For example, we determined it can be used to change the transition selection rules involving transfer of angular momentum. Also, more recently we have used structured beams to resolve the spatial extent of the wave-packet of an harmonic oscillator. This technique can be used also to determine the spatial wave functions of quantum wave-packets. I will present both current experimental status and prospects. Also I will discuss the application of structured beams to atomic clocks and the study of quantum thermodynamics.

Eloisa Cuestas

Capturing the Feshbach-induced Pairing Physics in the BEC-BCS Crossover

By including the effect of an external trap in a two-channel model for Feshbach resonances, we reproduce the experimental closed channel fraction across the BEC-BCS crossover and into the BCS regime of a 6 Li atomic Fermi gas. We also reproduce the measured binding energy of ultracold molecules in a 40 K Fermi gas. We provide general and near-resonance simple formulas for both observables. Contrary to the free-trap two-body theory and in line with experiments, our results predict a non vanishing closed channel fraction for fields above the resonance, which can be controlled by the trap frequency.

Anthony Brady

Relativistic frame-dragging and the Hong-Ou-Mandel dip -- a primitive to gravitational effects in multi-photon quantum-interference

We investigate the Hong-Ou-Mandel (HOM) effect − a two-photon quantum interference effect − in the space-time of a rotating spherical mass. In particular, we analyze a common-path HOM setup restricted to the surface of the earth and show that, in principle, general-relativistic frame-dragging induces observable shifts in the HOM dip. For completeness and correspondence with current literature, we also analyze the emergence of gravitational time-dilation effects in HOM interference, for a dual-arm configuration. The formalism thus presented establishes a basis for encoding general-relativistic effects into local, multi-photon, quantum-interference experiments.

Mayerlín Nuñez - Portela

Characterization of spectrally filtered heralded single photons

One method to produce pure heralded single photons (HSP) is by modifying, by means of spectral filters, the joint spectrum of the photon pairs produced via spontaneous parametric down conversion (SPDC). In this work, we characterize the dependence of the spectral purity and heralding efficiency of the HSP. The values we report for purity and heralding efficiency are obtained from measurements of the joint spectrum under different filtering conditions. Our results are in agreement with the theoretical model and complement similar measurements that have been done for heralded single photons produced by other type of sources

Gerard McCaul

Creating Driven Imposters with Quantum Control

The intrinsic properties of a material are those which uniquely identify it at equilibrium. What happens to these properties when the systems are driven from equilibrium however - is it possible to make one material mimic another? Here we answer this question using a framework for controlling the observables of a general correlated electron system driven by an incident laser field. The approach provides a prescription for the driving required to generate an arbitrary predetermined evolution for the expectation value of a chosen observable. To demonstrate this, we determine the laser fields required to exactly control the current in a Fermi-Hubbard system under a range of model parameters, fully controlling the current generated in the system. This is achieved for both the uncorrelated metallic-like state and one deep in the strongly correlated Mott insulating regime. Using the control strategy, it is possible to flip the optical responses of the two systems so as to mimic the other, creating “driven imposters”.

Heloise Chomet

Quantum bridges in phase space – Interference and Non-Classicality in Enhanced Ionisation

We perform a phase-space analysis of strong-field enhanced ionisation in molecules, with emphasis on quantum-interference effects. Using Wigner quasi-probability distributions and the quantum Liouville equation, we show that the primary cause of momentum gates is an interference-induced bridging mechanism that occurs if both wells in the molecule are populated. In the phase-space regions for which quantum bridges occur, the evolution of the Wigner function is essentially non-classical and non- adiabatic. Optimal conditions require minimising population trapping and using the bridging mechanism to feed into ionisation pathways along the field gradient.

Meet & Greet on Remo

Tuesday 24th November

Session: S4 Quantum computation, simulation, machine learning and quantum error correction

Karol Gietka

Quantum Simulators in Other Frames of Reference

Quantum simulators are highly-controllable systems that can be tuned or programmed to mimic physics of other often theoretically or experimentally intractable physical systems. In the case when a system is tuned to realize some other Hamiltonian the quantum simulator is called an analogue simulator; and when it is programmed according to the Trotter decomposition, it is called a digital quantum simulator. In my talk, I will present an alternative approach to quantum simulators in which I will show how two different Hamiltonians can in some situations give rise to the same physics. In particular, I will show how the Heisenberg XXX model with a staggered field can be used to mimic the most interesting physics of one-axis-twisting Hamiltonian. Finally, I will show how one can use this idea in digital quantum simulators.

Wooyeong Song

Tangible Reduction of Sample Complexity with Large Classical Samples and Small Quantum System

Quantum computation requires large classical datasets to be embedded into quantum states to exploit quantum parallelism. However, this embedding requires considerable resources. We consider a classical-quantum hybrid architecture, which allows large classical input, with a small-scale quantum system. This hybrid architecture is used to implement an oracle. It is shown that in the presence of noise in the oracle, the effects of internal noise can cancel each other out and improve the query success rate. Such an immunity of the oracle to noise directly reduces the sample complexity in the probably- approximately-correct (PAC) learning framework.

Omkar Srikrishna

Resource-efficient fault-tolerant quantum computation with optical hybrid states

We propose an all-linear-optical scheme to ballistically generate a cluster state for measurement-based topological fault-tolerant quantum computation (QC) using hybrid photonic qubits entangled in a continuous-discrete domain. In the presence of photon losses, we show that our scheme leads to a significant enhancement in both tolerable photon-loss rate and resource overheads. We report a photon-loss threshold of ~ 3.3 × 10^−3, which is higher than most of the known schemes. Furthermore, resource overheads to achieve a logical error rate of 10^−6 (10^−15) is estimated to be ~ 8.5 × 10^5 (1.7 × 10^7) which is significantly less by multiple orders of magnitude compared to other reported values.

Akshaya Jayashankar

Finding good quantum codes using the Cartan form

We present a simple and fast numerical procedure to search for good quantum codes for arbitrary noise processes, using the worst-case fidelity as the figure of merit. We reduce the complexity of the problem by fixing the form of the recovery to be a near-optimal recovery map, adapted to the noise in question. For qubit codes, we obtain a simple form for the objective function, which makes the optimization tractable. We parameterize our search space of encoding unitaries using the Cartan decomposition which allows us to search over the nonlocal parts of the encoded space, leading to families of channel-adapted codes.

Yin Mo

Covariant Quantum Error Correcting Codes via Reference Frames

Error correcting codes with a universal set of transversal gates are the desiderata of realising quantum computing. Such codes, however, are ruled out by the Eastin-Knill theorem. Moreover, it also rules out codes which are covariant with respect to the action of transversal unitary operations forming continuous symmetries. In this work, starting from an arbitrary code, we construct approximate codes which are covariant with respect to local SU(d) symmetries using quantum reference frames. We show that our codes are capable of efficiently correcting different types of erasure errors. When only a small fraction of the n qudits upon which the code is built are erased, our covariant code has an error that scales as $1/n^2$, which is reminiscent of the Heisenberg limit of quantum metrology. When every qudit has a chance of being erased, our covariant code has an error that scales as 1/n. We show that the error scaling is optimal in both cases. Our approach has implications for fault-tolerant quantum computing, reference frame error correction, and the AdS-CFT duality.

Awareness Session

Science and Media

On quantum hype and responsible communication

Tara Roberson (Australian Research Council Centre of Excellence for Engineered Quantum Systems) The ‘second quantum revolution’ has been the subject of substantial speculation and media hype. This hype, or simplified and sensationalised science, appears to be inescapable in quantum science at this moment. The negative effects of hype are familiar. The question is whether hype is always a distortion and a lie, or can it be redeemed? In this talk, we will discuss different aspects of quantum hype and discuss how we might responsibly communicate about quantum technologies.

Meet & Greet on Remo

Session: S5 Quantum cryptography

Chrysoula Vlachou

Analytic quantum weak coin flipping protocols with arbitrarily small bias

Weak coin flipping (WCF) is the strongest known primitive for secure two-party computation with arbitrarily close to perfect security quantumly, while classically its security is completely compromised, without further assumptions, e.g. computational hardness. In 2007 Mochon proved the existence of WCF protocols with almost perfect security, however the construction of such protocols remained hard mainly due to non-constructive parts of the formalism involved in the proof of existence. Here, we present new techniques which yield a fully analytical construction of WCF protocols with arbitrary security, thus achieving a solution that was missing for more than a decade.

Jadwiga Wilkens

Semi-device-dependent blind quantum tomography

Extracting tomographic information about quantum states is a crucial task in the quest towards devising high-precision quantum devices. Current schemes typically require measurement devices for tomography that are a priori calibrated to a high precision. Ironically, the accuracy of the measurement calibration is fundamentally limited by the accuracy of state preparation, establishing a vicious cycle. Here, we prove that this cycle can be broken and the fundamental dependence on the measurement devices significantly relaxed. We show that exploiting the natural low-rank structure of quantum states of interest suffices to arrive at a highly scalable blind tomography scheme with a classically efficient post-processing algorithm. We further improve the efficiency of our scheme by making use of the sparse structure of the calibrations. This is achieved by relaxing the blind tomography problem to the task of de-mixing a sparse sum of low-rank quantum states. Building on techniques from model-based compressed sensing, we prove that the proposed algorithm recovers a low-rank quantum state and the calibration provided that the measurement model exhibits a restricted isometry property. For generic measurements, we show that our algorithm requires a close-to-optimal number measurement settings for solving the blind tomography task. On the way, we establish evidence that classically-efficiently and sample-optimally solving the blind tomography task is NP-hard.

Raja Yehia

Composable Security for Multipartite Entanglement Verification

We present a multipartite entanglement verification protocol for n parties con- sisting only in local quantum operations and authenticated classical communication once a state is shared among them and providing composable security against a malicious source. It can be used as a secure subroutine in the Quantum Internet to test if a source is sharing quantum states that are at least ϵ-close to the GHZ state before performing a communication or computation protocol. Using the Abstract Cryptography framework, we can readily compose our basic protocol in order to create a composably secure multi-round protocol enabling honest parties to obtain a state close to a GHZ state or an abort signal, even in the presence of a noisy or malicious source.

Coffee break

Giacomo Carrara

Genuine multipartite entanglement is not a precondition for secure conference key agreement

Entanglement plays a crucial role in the security of quantum key distribution. A secret key can only be obtained by two parties if there exists a corresponding entanglement-based description of the protocol in which entanglement is witnessed, as shown by Curty et al (2004). Here we investigate the role of entanglement for the generalization of quantum key distribution to the multipartite scenario, namely conference key agreement. In particular, we ask whether the strongest form of multipartite entanglement, namely genuine multipartite entanglement, is necessary to establish a conference key. We show that, surprisingly, a non-zero conference key can be obtained even if the parties share biseparable states in each round of the protocol. Moreover we relate conference key agreement with entanglement witnesses and show that a non-zero conference key can be interpreted as a non-linear entanglement witness that detects a class of states which cannot be detected by usual linear entanglement witnesses.

Cristina Cirstoiu

Robustness of Noether's principle: Maximal disconnects between conservation laws and symmetries in quantum theory

To what extent does Noether's principle apply to quantum channels? We quantify the degree to which imposing a symmetry constraint on quantum channels implies a conservation law and show that this relates to physically impossible transformations in quantum theory, such as time reversal and spin inversion. In this analysis, the convex structure and extremal points of the set of quantum channels symmetric under the action of a Lie group G becomes essential. It allows us to derive bounds on the deviation from conservation laws under any symmetric quantum channel in terms of the deviation from closed dynamics as measured by the unitarity of the channel. In particular, we investigate in detail the U(1) and SU(2) symmetries related to energy and angular momentum conservation laws. In the latter case, we provide fundamental limits on how much a spin-j_A system can be used to polarize a larger spin-j_B system, and on how much one can invert spin polarization using a rotationally symmetric operation. Finally, we also establish novel links between unitarity, complementary channels, and purity that are of independent interest.

Ophelia Crawford

Efficient quantum measurement of Pauli operators in the presence of finite sampling error

Estimating the expectation value of an operator corresponding to an observable is a fundamental task in quantum computation. It is often impossible to obtain such estimates directly, as the computer is restricted to measuring on a fixed computational basis. One common solution splits the operator into a weighted sum of Pauli operators and measures each separately, at the cost of many measurements. An improved version collects mutually commuting Pauli operators together before measuring all operators within a collection simultaneously. The effectiveness of doing this depends on two factors. Firstly, we must understand the improvement offered by a given arrangement of Paulis in collections. In our work, we propose two natural metrics for quantifying this, operating under the assumption that measurements are distributed optimally among collections so as to minimise the overall finite sampling error. Motivated by the mathematical form of these metrics, we introduce SORTED INSERTION, a collecting strategy that exploits the weighting of each Pauli operator in the overall sum. Secondly, to measure all Pauli operators with a collection simultaneously, a circuit is required to rotate them to the computational basis. In our work, we present two efficient circuit constructions that suitably rotate any collection of k commuting n-qubit Pauli operators using at most kn-k(k+1)/2 and O(kn/\log k) two-qubit gates respectively. The methods are numerically illustrated in the context of the Variational Quantum Eigensolver, where the operators in question are molecular Hamiltonians. As measured by our metrics, SORTED INSERTION outperforms four conventional greedy colouring algorithms that seek the minimum number of collections.

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Poster Session I

Meet & Greet on Remo

Session: S6 Quantum computation, simulation, machine learning and quantum error correction

James Whitfield (invited)

Simulating fermions with qubits

Electrons are remarkable to experience in our everyday world dictating heavily the properties of the things around us. However, as fermions, electrons must satisfy certain conditions on their wave function. This complicates simulating them with computers, quantum or otherwise, and this has led to many schemes for manipulating them. In this lecture, I want to review the work that my group and others have been doing to simulate fermions using qubits. I will discuss the merits of various methods of simulating systems of interacting fermion using matchgates, first quantization, and both unitary (e.g. Jordan-Wigner) and ancillary (e.g. fermion codes) methods for second quantization. The encoding constructions presented will only become more important as quantum simulations of molecules and materials scale up to more practical sizes.

Abhinav Deshpande

The importance of the spectral gap in estimating ground-state energies

We study the role played by the spectral gap in the complexity of the LocalHamiltonian problem. To do so, we consider the setting in which one estimates the ground-state energy to within inverse exponential precision. In this setting, the complexity of LocalHamiltonian is magnified from QMA to PSPACE. We show that the full complexity of the high precision case only comes about when the spectral gap is exponentially small. We also obtain implications for the representability and circuit complexity of ground states of local Hamiltonians, uniqueness of quantum witnesses, and amplification of quantum witnesses in the presence of postselection.

Lane Gunderman

Local-dimension-invariant qudit stabilizer codes

To have a useful and controllable quantum computer we need to protect our information from noise. One option is to reduce the number of particles that need protection, while still maintaining a large computational space, by using qudits instead of qubits. These qudits will need codes to protect their information as well, however, the primary focus has been on qubit codes so most qudit codes have very challenging relations between the parameters of the code. These relations mean that an experimenter might have to not utilize some of their qudits since there are no known codes using their exact relation between those parameters. Generally qudit codes are found through the CSS theorem, however, a few examples of codes are known which have no dependency on their local dimension, while still maintaining their distance. My recent work builds off these fortuitous examples, showing that any stabilizer code over q levels can be used as a code for any qudit system. This greatly reduces the restrictions on the relations between parameters. In the case of non-degenerate codes we have shown that these invariant forms of these codes are guaranteed to at least preserve the distance of the code beyond some cutoff value p*. In some regards one may consider this a tool similar in nature to CSS code construction: CSS allows classical to quantum code construction whereas this allows for quantum to quantum code construction.

Bruno Ronchi

Maximizing information obtainable by quantum sensors with the Quantum Zeno Effect

A quantum sensor is a device to obtain information about its environment at the molecular or nanometric scales. We consider a 1/2-spin as a magnetic field sensor, subjected to periodic projective measurements. Coherent evolution of the quantum sensor, combined with projective measurements; induce an exponential decay. We demonstrate with quantum information theory that when an off-resonance alternating magnetic field is probed, the projective evolution magnifies information on the magnetic field's strength. We define the parameter regimes where this inference protocol outperforms the free evolution of the sensor. We show applications of the method for determining molecular structures with quantum sensors.

Alba Cervera Lierta

Data re-uploading for a universal quantum classifier

A single qubit provides sufficient computational capabilities to construct a universal quantum classifier when assisted with a classical subroutine. This fact may be surprising since a single qubit only offers a simple superposition of two states and single-qubit gates only make a rotation in the Bloch sphere. The key ingredient to circumvent these limitations is to allow for multiple data re-uploading. A quantum circuit can then be organized as a series of data re-uploading and single-qubit processing units. Furthermore, both data re-uploading and measurements can accommodate multiple dimensions in the input and several categories in the output, to conform to a universal quantum classifier. The extension of this idea to several qubits enhances the efficiency of the strategy as entanglement expands the superpositions carried along with the classification. Extensive benchmarking on different examples of the single- and multi-qubit quantum classifier validates its ability to describe and classify complex data.

Poster Session II

Meet & Greet on Remo

Wednesday 25th November

Session: S7 Quantum foundations

Mio Murao (invited)

Higher-order quantum operations of blackbox unitaries

Supermaps are higher-order transformations taking maps as input. Quantum mechanically implementable supermaps are called quantum supermaps and their general properties are formulated by the framework of quantum networks and quantum combs proposed by Chiribella et al. We consider the implementability of supermaps in quantum mechanics when the input maps are unitaries given as blackboxes and the unitary blackboxes can be used multiple but finite times to explore fundamental quantum properties exhibited in higher-order transformations possibly utilized for quantum computation. We regard such direct implementations of supermaps for blackbox quantum operations with multiple uses of the blackboxes as “higher-order quantum operations”. We investigate how the causal structure and spacetime symmetry of these unitary blackboxes affects their performance in implementing higher-order quantum operations. We analyze two tasks, inversion of blackbox unitaries and controllization of divisible blackbox unitaries based on controllization of quantum combs.

Wataru Yokojima

Consequences of preserving reversibility in quantum superchannels

Similarly to quantum states, quantum operations can also be transformed by means of quantum superchannels, also known as process matrices. Quantum superchannels with multiple slots are deterministic transformations which take causally independent quantum operations as inputs and are enforced to respect the laws of quantum mechanics but the use of input operations may lack a definite causal order. While causally ordered superchannels admit a characterization in terms of quantum circuits, a similar characterization of general superchannels in terms of standard quantum objects with a clearer physical interpretation has been missing. In this paper we provide a mathematical characterization for pure superchannels with two slots (also known as bipartite pure processes), which are superchannels preserving the reversibility of quantum operations. We show that the reversibility preserving condition restricts all pure superchannels with two slots to be either a causally ordered quantum circuit only consisting of unitary operations or a coherent superposition of two pure causally ordered circuits. The latter may be seen as a generalization of the quantum switch, allowing a physical interpretation for pure two-slot superchannels. An immediate corollary is that purifiable bipartite processes cannot violate device-independent causal inequalities.

Graeme Berk

Resource Theories of Quantum Processes

Environment induced noise is an ever-present challenge in the development of quantum technologies: almost every quantum computer must be treated as an open system, and every quantum thermal machine must interact with some form of thermal bath. However, not all noisy environments are equal — some effectively destroy information, while others only hide it. The latter class of environments are of key interest. We focus on the property of certain types of environments which have some ability to 'remember' the system's past — a widely present phenomenon known as non- Markovianity. It has been suggested that non-Markovianity can be exploited to enhance performance in tasks such as quantum control and work extraction. Our contribution is to quantify this type of advantage by providing a consistent and generally applicable resource theory framework for comparing the relative utility of processes induced by different environments. To demonstrate the power of our newly developed framework for resource theories of multi-time quantum processes, we analyse a class of experimental scenarios with varying levels of control. In almost all of the corresponding resource theories, some form of temporally complex phenomena was found to be useful, including one where non-Markovianity is the precise quantity that aids the experimenter in achieving their goals. These resource theories also are applicable to a plethora of other physical scenarios; examples may include error mitigation for correlated noise, thermal machines with structured baths, or enhancing quantum communication between parties.

Christina Giarmatzi

Witnessing quantum memory in non-Markovian processes

We present a method to detect quantum memory in a non-Markovian process. We call a process Markovian when the environment does not provide a memory that retains correlations across different system-environment interactions. We define two types of non-Markovian processes, depending on the required memory being classical or quantum. We formalise this distinction using the process matrix formalism, through which a process is represented as a multipartite state. Within this formalism, a test for entanglement in a state can be mapped to a test for quantum memory in the corresponding process. This allows us to apply separability criteria and entanglement witnesses to the detection of quantum memory. We demonstrate the method in a simple model where both system and environment are single interacting qubits and map the parameters that lead to quantum memory. As with entanglement witnesses, our method of witnessing quantum memory provides a versatile experimental tool for open quantum systems.

Shrikant Utagi

Quantum causal correlations and non-Markovianity of quantum evolution

A novel non-Markovianity (NM) measure is introduced based on causality measure (CM)- recently introduced by Fitzimons et.al., Scientific reports, 5:18281, (2015) - which quantifies temporal (causal) correlations. The measure is justified with the example of a qubit interacting with a bosonic reservoir with Jaynes-Cummings type of interaction. Breakdown of monotonicity of CM is shown to be associated with negativity of the decay rate in the master equation hence the non-Markovian nature of the channel.

Poster Session III

Meet & Greet on Remo

Session: S8 Experiment

Konstantina Koteva

Silicon quantum photonic device for multidimensional controlled unitaries

We present a fully reconfigurable silicon quantum photonic device capable of performing controlled four-dimensional unitary operations with 0.84±0.02 fidelity. We report its characterisation by process tomography and deploy it to successfully perform a quantum model learning protocol.

Valeria Saggio

Experimental few-copy multipartite entanglement detection

An essential task in scalable quantum technologies is the verification of entanglement in quantum systems. Although significant effort has been put into developing protocols that aim at minimizing the experimental requirements, this task remains challenging when dealing with large quantum systems. Here, a protocol is presented where a novel probabilistic framework enables high-confidence entanglement verification with only a remarkably small number of copies of quantum states. To benchmark the theoretical findings, the protocol is applied to an experimentally generated photonic six-qubit cluster state. It is demonstrated that the presence of entanglement is verified with a confidence of at least 99.74% by using only 20 copies of the state, and that genuine six-qubit entanglement is detected with at least 99% confidence by using only 112 copies of state.

Mario Krenn

Conceptual understanding through efficient inverse-design of quantum optical experiments

Artificial intelligence (AI) is a potentially disruptive tool for physics and science in general. One crucial question is how this technology can contribute at a conceptual level, and contribute new scientific understanding. Scientists used AI techniques to re-discover previously known concepts, but so far it is not clear how to apply these methods to open problems for getting new scientific concepts and ideas. I will present Theseus, an algorithm that can provide new conceptual understanding, and we demonstrate it in the field of experimental quantum optics. To do so, we make four crucial contributions. (i) We introduce an interpretable representation of quantum optical experiments that can be used algorithmically. (ii) We develop an inverse-design approach for new quantum experiments, which is orders of magnitudes faster than the best previous algorithms. (iii) We solve several crucial open questions in experimental quantum optics, which could lead to progress in photonic technology. Finally, and most importantly, (iv) the interpretable representation and enormous speedup allow us to produce solutions that a human scientist can interpret and gain new scientific concepts from outright. We anticipate that Theseus will become an essential tool in quantum optics for developing new experiments and photonic hardware. It can further be generalized to answer open questions and provide new concepts in a large number of other quantum physical questions beyond quantum optical experiments. Theseus is a demonstration of explainable AI (XAI) in physics that shows a way how AI algorithms can contribute to science on a conceptual level.

Coffee break

Vatshal Srivastav

Genuine high-dimensional quantum steering

We theoretically formalise and experimentally demonstrate a notion of genuine high-dimensional quantum nonlocal steering. We show that high-dimensional entanglement combined with judiciously chosen local measurements leads to a stronger form of steering, provably impossible to obtain via entanglement in lower dimensions. Exploiting the connection between steering and incompatibility of quantum measurements, we derive simple two-setting steering inequalities for certifying the presence of genuine high-dimensional steering. We report the experimental violation of these inequalities using macro-pixel photon-pair entanglement demonstrating genuine high- dimensional steering in dimensions up to d =15.

Markus Hiekkamäki

Single-path Two-photon Interference Effects Between Spatial Modes

Enabled by recent advances, we demonstrate the first two-photon interference solely between transverse spatial modes of photons, in a single beamline. By also scaling the effect up to 4 dimensions, through spatial-mode multiports, we take a crucial step towards implementing single-path linear optical networks utilizing the high-dimensional state space of photon spatial modes.

Awareness Session

Mental Health in Scientific Research

Dr. Senaida Hernández Santana (Universidad Politécnica de Madrid) will interview Michelle Reynolds, MA. Michelle is a Psychoanalytical Psychotherapist, Cognitive Analytic Therapist & senior supervisor. Her core profession is Social Work having specialised in Adult and Child psychiatry. Currently, Head of the Staff Counselling Centre at the University of Cambridge, and Assistant Director at the Health, Safety, and Regulated Facilities Division.

Meet & Greet on Remo

Session: S9 Entanglement theory

Armin Tavakoli

Powering correlations with information

Quantum communication is commonly quantified in terms of the dimension of Hilbert space. Here, we introduce and investigate correlations that arise from informationally restricted communication. This information-based framework makes no reference to dimension and instead employs entropic quantifiers of information. We fully characterise classical correlations and show that quantum correlations violate such constraints. We also prove that information-bounded quantum correlations are strictly stronger than dimension-bounded quantum correlations. We present a semidefinite programming hierarchy to characterise the quantum set and discuss how the concept applies to other topics in quantum information science and quantum foundations.

Andrés Ducuara

Operational interpretation of weight-based resource quantifiers in convex quantum resource theories

We introduce the resource quantifier of weight of resource for convex quantum resource theories of states and measurements with arbitrary resources. We show that it captures the advantage that a resourceful state (measurement) offers over all possible free states (measurements) in the operational task of exclusion of subchannels (states). Furthermore, we introduce information-theoretic quantities related to exclusion for quantum channels and find a connection between the weight of resource of a measurement and the exclusion-type information of quantum-to-classical channels. Our results apply to the resource theory of entanglement in which the weight of resource is known as the best-separable approximation or Lewenstein-Sanpera decomposition introduced in 1998. Consequently, the results found here provide an operational interpretation to this 21-year-old entanglement quantifier.

Clément Meignant

Rates of multi-partite entanglement transformations

The rates at which bi-partite entangled states can be asymptotically transformed are fully determined. In the multi-partite setting, a similar question of the optimally achievable rates of transforming one pure state into another is notoriously open. In this work, we report substantial progress by deriving simple upper and lower bounds on the rates that can be achieved in asymptotic multi-partite entanglement transformations. These bounds are based on ideas of entanglement combing and state merging. We identify cases where the bounds coincide and hence provide the exact rates. This result provides further scope for quantum internet applications beyond points-to-point.

Patricia Contreras-Tejada

Genuine multipartite nonlocality is intrinsic to quantum networks

Quantum entanglement and nonlocality are inextricably linked. While necessary, entanglement is not always sufficient for nonlocality, in Bell scenarios. We derive sufficient conditions for entanglement to produce genuine multipartite nonlocality (GMNL) in networks. We show that any connected network of bipartite pure entangled states is GMNL, independently of topology and amount of entanglement shared. We deduce that all pure genuine multipartite entangled (GME) states are GMNL in the sense that measurements exist on nitely many copies of any GME state that yield a GMNL behaviour. Our results pave the way towards feasible manners of generating GMNL using any connected network.

Nicolás Gigena

One-body entanglement as a resource

We show that one-body entanglement, which is a measure of the deviation of a fermionic state from a Slater Determinant (SD) and is determined by the mixedness of the single particle density matrix, can be considered as a quantum resource. The associated theory has SDs and their convex hull as free states, and fermion linear optics operations, which include one-body unitary transformations and measurements of the occupancy of single particle modes, as basic free operations. It is shown that this resource is consistent with a model of fermionic quantum computation which requires correlations beyond antisymmetrization.

Awareness Session

Science is Not a Safe Space

Sarah Kaiser (Q# Community). In this session, I want to talk about how we can make science a welcoming and supportive place for everyone! I will outline some of the problems that we face when trying to make changes in our communities, as well as what tools I have found helpful in making change in my communities. With this context, we will open it up to a larger discussion with Ruth Oulton (University of Bristol), Emma Chapman (Imperial College London), and Juani Bermejo-Vega on their experiences in making our communities safer.

Meet & Greet on Remo

Thursday 26th November

Session: S10 Quantum foundations

Harshit Verma

Effect of environment on the interferometry of clocks

Mach-Zehnder (MZ) interferometry, involving spatial superposition of a massive particle with its internal degrees of freedom (DOF), modelled as clocks, had been previously proposed as an experiment encapsulating genuine general relativistic effects on quantum systems. We have analysed a realistic model of the clocks in which they are subject to the effects of the environment leading to noise during their transit through the arms of the interferometer. We have shown that interferometric visibility is affected by the type of noise and also the time scale and transition probabilities in the noise models representing the environmental effects.

Shishir Khandelwal

Universal modifications to time dilation in quantum clocks

The general theory of relativity associates a proper time with objects via their world-lines classical trajectories forbidden by quantum theory. Here we demonstrate that in the post-Newtonian limit, “good” quantum clocks with classical states of motion, experience time dilation as dictated by general relativity. For nonclassical states of motion, however, we find that quantum interference leads to a significant modification to general relativistic time dilation. Moreover, we show that the ignorance of the clock’s state of motion leads to a larger uncertainty in time measurements, a consequence of the entanglement of the clock’s time and motional degrees of freedom.

Lorenzo Maccone

Quantum measurements of time

We propose a time-of-arrival operator in quantum mechanics by conditioning on a quantum clock. This allows us to bypass some of the problems of previous proposals, and to obtain a Hermitian time of arrival operator whose probability distribution arises from the Born rule and which has a clear physical interpretation. The same procedure can be employed to measure the ”time at which some event happens" for arbitrary events (and not just specifically for the arrival time of a particle).

Awareness Session

Disability and Academia

Sofia Qvafort (University College London & Imperial College London). What's it like to work as a physicist when you have a disability? In my talk, I will tell you about my experiences of studying and working as a researcher while being visually impaired. I will also discuss the barriers to disabled researchers in the current academic landscape and discuss things we can all do together to improve the situation for disabled researchers.

Meet & Greet on Remo

Session: S11 Entanglement theory

Flavio Baccari

Self-testing Bell inequalities from the stabiliser formalism and their applications

I will introduce a powerful tool to construct self-testing Bell inequalities from the stabiliser formalism and present two applications in the framework of device-independent certification protocols. Firstly, I will show how the method allows to derive Bell inequalities maximally violated by the family of multi-qubit graph states and suited for their robust self-testing. Secondly, I will present how the same method permits to introduce the first examples of subspace self-testing, a form of certification that the measured quantum state belongs to a given quantum error correction code subspace, which remarkably includes also mixed states.

Mateus Araújo

Bell nonlocality with a single shot

In order to reject the local hidden variables hypothesis, the usefulness of a Bell inequality can be quantified by how small a p-value it will give for a physical experiment. Here we show that to obtain a small expected p-value it is sufficient to have a large gap between the local and Tsirelson bounds of the Bell inequality, when it is formulated as a nonlocal game. We develop an algorithm for transforming an arbitrary Bell inequality into an equivalent nonlocal game with the largest possible gap, and show its results for the CGLMP and Inn22 inequalities. We present explicit examples of Bell inequalities with gaps arbitrarily close to one, and show that this makes it possible to reject local hidden variables with arbitrarily small p-value in a single shot, without needing to collect statistics. We also develop an algorithm for calculating local bounds of general Bell inequalities which is significantly faster than the naïve approach, which may be of independent interest.

Hyejung Hailey Jee

Characterising quantum correlations of fixed dimension

We give a converging semidefinite programming hierarchy of outer approximations for the set of quantum correlations of fixed dimension. Starting from the Navascués-Pironio-Acín (NPA) hierarchy, we identify additional semidefinite constraints for any fixed dimension, which lead to analytical bounds on the convergence speed. In particular, we give an algorithm to compute additive ε-approximations on the value of two-player free games of $|T| \times |T|$-dimensional quantum assistance in time which scales polynomially in $|Q|$ and quasi-polynomially in $|A|$, where $|Q|$ and $|A|$ are the numbers of questions and answers, respectively. This improves previously known approximation algorithms which were at best exponential in |Q||A|.

Coffee break

Jiri Guth Jarkovsky

Efficient description of many-body systems with Matrix Product Density Operators

Matrix Product States form a powerful ansatz for the simulation of one-dimensional quantum systems that are in a pure state. Their power stems from the fact that they faithfully approximate states with a low amount of entanglement, the “area law”. However, in order to accurately capture the physics of realistic systems, one generally needs to apply a mixed state description. In this work, we establish the mixed state analogue of this characterization: We show that one-dimensional mixed states with a low amount of entanglement, quantified by the entanglement of purification, can be efficiently approximated by Matrix Product Density Operators.

Peter Brown

An unbounded number of independent observers can share the nonlocality of a single maximally entangled qubit pair

Alice and Bob each have half of a pair of entangled qubits. Bob measures his half and then passes his qubit to a second Bob who measures again and so on. The goal is to maximize the number of Bobs that can have an expected violation of the Clauser-Horne-Shimony-Holt (CHSH) Bell inequality with the single Alice. This scenario was introduced in where the authors mentioned evidence that when the Bobs act independently and with unbiased inputs then at most two of them can expect to violate the CHSH inequality with Alice. Here we show that, contrary to this evidence, arbitrarily many independent Bobs can have an expected CHSH violation with the single Alice. Our proof is constructive and our measurement strategies can be generalized to work with a larger class of two-qubit states that includes all pure entangled two-qubit states.

Awareness Session

Black Community in Academia

Dr. Carlos Parra chair/moderator (CALEO Consulting GmbH, Germany)

Dr. Bárbara Rosa (Cambridge Graphene Centre, UK)

Topic: Science and racism - Racism as a systematic problem

Prof. Katemari Rosa (Federal University of Bahia, Brazil)

Topic: Decolonizing science: rethinking human knowledge and intellectuality

Dr. Mathys Rennela (Leiden University. Germay)

Topic: Challenges faced by Black academics in Europe

Assoc. Prof. Cornelius Mduduzi Masuku (Purdue University, USA)

Topic: Support for first-generation college students. (Most black students struggle with a lot of issues in college and lack support on various fronts, be it Academic support – from Professors and Staff; or Financial support – from Scholarships or Companies or Family; or Social support; etc. I'm planning to touch on these and highlight some coping mechanisms and survival strategies and also encourage discussion on these.)

Dr. Juan David González Calderon. (Uniremington Medellín, Colombia)

Topic: The absence of black people in academia in Colombia: A proof of the structural racism and inequality

Meet & Greet on Remo

Session: S12 Quantum foundations

Farid Shahandeh (invited)

Contextuality of general probabilistic theories

Contextuality refers to the idea that context-independent classical models for some measured statistics are infeasible. There are two major approaches to construct models to explain the statistics collected in experiments. It is possible to adopt an ontic view and construct a classical probabilistic model, aka an ontological model. Or, one can take an operational position and construct an operational theory that (in principle) attempts to be modest and make no assumptions about ontic properties of the system. Such minimalist operational theories, like quantum mechanics in its orthodox interpretation, are captured within the framework of general probabilistic theories (GPTs). Here, I answer the question what (non)contextuality means for both of these approaches. I'm also particularly interested to understand the structural properties that make a given GPT (non)contextual.

Matthew Leifer

Noncontextuality Inequalities from Antidistinguishability

Noncontextuality inequalities are usually derived from the distinguishability properties of quan- tum states, i.e. their orthogonality. Here, we show that antidistinguishability can also be used to derive noncontextuality inequalities. The Yu-Oh 13 ray noncontextuality inequality can be re-derived and generalized as an instance of our antidistinguishability method. For some sets of states, the antidistinguishability method gives tighter bounds on noncontextual models than just considering orthogonality, and the Hadamard states provide an example of this. We also derive noncontextuality inequalities based on mutually unbiased bases and symmetric informationally complete POVMs.

Shiv Akshar Yadavalli

Contextual advantage for noisy one-shot classical communication assisted by entanglement

We study the noise-robust generalisation of an earlier proposed strategy that considers the enhancement of one-shot zero-error capacity of certain Kochen-Specker hypergraph-based classical channels assisted by noiseless entanglement. Our general analysis considers the enhancement of the one-shot success probability of sending a fixed set of classical messages over general classical channels assisted by noisy entangled states and/or local measurements. We demonstrate the necessity and sufficiency of contextuality for quantum advantage, identifying contextuality as the key nonclassical feature for this task. We further highlight graph-theoretic properties of certain classical channels and bound the enhancement with graph-theoretic witnesses of contextuality.

Susane Calegari

Contextuality and memory cost of simulation of Majorana fermions

We show that the presence of contextuality places new lower bounds on the memory cost for classically simulating restricted classes of quantum computation. We apply our result to simulations of topological quantum computing (TQC) with Ising anyons, a model of quantum computation based on braiding Majorana fermions. For the classical simulation of n fermionic modes, we find that the memory cost is lower bounded by n.log(n). We show that this lower bound is tight. TQC model lies in the intersection between two computational models: Clifford group and fermionic linear optics (FLO), a framework analogous to bosonic linear optics. We extend our results and prove that the lower bound in the memory required in an approximate simulation of the FLO model is quadratic on the number of fermionic modes.

Coffee break

John Selby

Compositional resource theories of coherence

Quantum coherence is one of the most important resources in quantum information. Recently, there has been substantial progress in developing mathematical resource theories of coherence, paving the way towards its quantification and control. To date however, these resource theories have only been mathematically formalised within the realms of convex-geometry, information theory, and linear algebra. This approach is limited in scope, and makes it difficult to go beyond resource theories of coherence for single system quantum states relative to some fixed basis. In this talk, based on a recent paper with Ciarán M. Lee (arXiv: 1911.04513), I take a complementary perspective, showing that resource theories of coherence can instead be defined purely compositionally, that is, working with the mathematics of process theories, string diagrams and category theory. In this talk I will outline the basics of this approach and highlight a few of the key dividends afforded by this new perspective.

Borivoje Dakic

Spatial superpositions as a resource for quantum information processing

Generally speaking, communication is the process of transmitting a message (information) from a sender to a receiver. When the distant parties use a single information carrier to communicate (e.g. single particle), they are restricted to “one-way signaling”, as the information flows in one direction only. In this talk, I will analyze the corresponding quantum scenario, where the parties communicate via a single quantum information carrier prepared in superposition of different spatial locations. Surprisingly, I will show that such a scenario results in “multi-way signaling”, which is impossible in classical physics. Our framework does not assume (a priori) the use of quantum entanglement, in contrast to the majority of known quantum information tasks and protocols. These findings bring novel insights into quantum information processing, ranging from foundational to practical.

David Schmid

Unifying entanglement, nonlocality, steerability, and more

We show that a wide array of useful resources that have been previously studied in the context of space-like separation can all be subsumed under one unified notion of nonclassicality. We define a single resource theory which subsumes all of these as special cases, and which allows for comparisons of resourcefulness across arbitrary resource types.

Meet & greet on Remo

Friday 27th November

Session: S13 Entanglement theory

Closing remarks

First of three closing sessions aimed at UTC+1.

Aravinda S

Creating ensembles of dual unitary and maximally entangling quantum evolutions

Entanglement of unitary operators quantified in terms of operator entanglement, and average entanglement created by the unitary evolution quantified as entangling power, has paramount importance in quantum information theory as well as in many-body physics. The unitaries that maximize operator entanglement, called dual unitaries, can be used as an ingredient for analytically solvable nonintegrable many-body systems. Thus it is an open question as to how to construct dual unitaries in arbitrary dimen- sions. In this work we provide an efficient iterative method to generate an ensemble of such dual unitaries having maximal operator entanglement and entangling power acting on bipartite quantum systems.

Yu Xiang

Distribution of multipartite Einstein-Podolsky-Rosen steering in Gaussian systems

Understanding how quantum resources can be quantified and distributed over many parties has profound applications in quantum communication. As one of the most intriguing features of quantum mechanics, Einstein-Podolsky-Rosen (EPR) steering is a useful resource for secure quantum networks. Here, we present an experimental generation of a highly versatile and flexible repository of multipartite steering using an optical frequency comb and ultrafast pulse shaping. Simply modulating the optical spectral resolution of the detection system, this scheme is able to produce on-demand 4, 8 and 16-mode Gaussian steering without changing the photonics architecture. We observe a very rich structure for the steering distribution, which offers a powerful foundation for constructing quantum networks in real-world scenarios.

Giulio Gianfelici

Detecting entanglement of unknown continuous-variable states with random measurements

We explore the possibility of entanglement detection in continuous-variable systems by entanglement witnesses based on covariance matrices, constructible from random homodyne measurements. We propose new linear constraints characterising the entanglement witnesses based on second moments, and use them in a semidefinite program providing the optimal entanglement test for given random measurements. We test the method on the class of squeezed vacuum states and study the efficiency of entanglement detection in general unknown covariance matrices.

Massimo Frigerio

Nonclassical steering and the Gaussian steering triangoloids

We fully characterize the mechanism by which nonclassicality according to the Glauber P-function can be conditionally generated on one mode of a two-mode Gaussian quantum state by generic Gaussian measurements on the other mode. For two-mode squeezed thermal states, we visualize the whole set of conditional states constructing Gaussian steering triangoloids and we show that nonclassicality can be induced in this way if and only if the initial state is EPR-steerable. In the more general case, we recognize two types of quantum correlations: weak and strong nonclassical steering, the former being independent of entanglement, and the latter implying EPR steerability.

Sumeru Hazra

Highly Connected Qubit Network Using Multimodal Circuits as Building Blocks

Superior inter-qubit connectivity and higher dimensional gates enable efficient implementation of quantum algorithms in quantum processors. Most superconducting quantum processors typically have nearest neighbour connectivity and use native two-qubit gates only. Multimodal circuits like the trimon, offer an alternative implementation of multi-qubit blocks with high fidelity native multi-qubit gates. Here, we experimentally demonstrate a multi-qubit gate between a multimodal system and a conventional transmon qubit and explain how it can be scaled to make a highly connected network of multi-modal systems.

Santiago Tarragó Vélez

Bell correlations between light and vibrations at ambient conditions

Mechanical oscillators have been identified as new resources for quantum optics and its applications in metrology, sensing and information processing. Developing new techniques to prepare non-classical states of mechanical oscillators and engineer their quantum correlations with light fields also promises new insights into the dynamics and decoherence of vibrations in the quantum regime. This talk describes a new ultrafast pump-probe Raman spectroscopy technique that harnesses time-correlated single-photon counting to prepare and characterise non-classical states of Raman-active vibrations in crystals and molecules.

Catalina Curceanu

Collapse models tested at the Gran Sasso underground laboratory

One of the predictions of the Collapse Models, in particular of the Continuous Spontaneous Localization model, is the emission of a spontaneous radiation, which can be tested by high-sensitivity experiments performed in extremely low-background laboratories. We shall present the latest results obtained by running such a dedicated experiment at the Gran Sasso underground laboratory, which allowed us to obtain the best limits on the CSL model parameters in a broad parameters space. We also discuss future perspectives and the impact of our findings for quantum technologies.

Jack Clarke

Creating quantum states of mechanical motion via pulsed optomechanics

Cavity quantum optomechanics utilizes the radiation-pressure interaction between light and a moveable mechanical object inside a cavity for applied and fundamental physics. When combined with the tools of quantum optics, optomechanics provides a route for engineering non-classical states of motion in a more macroscopic regime. We explore the pulsed regime of cavity quantum optomechanics, which utilizes pulses of light much shorter than a mechanical period, for mechanical quantum state engineering applications. In particular, we propose protocols for preparing mechanical superposition states and entanglement between two massive oscillators.

Meet & Greet on Remo

Session: S14 Quantum information and communication theory

Closing remarks

Matteo Rosati

Classical capacity of quantum Gaussian codes without a phase reference: when squeezing helps

We study the rate of classical information transmission using quantum Gaussian states without a phase-reference frame. We consider a family of phase noise channels with a finite decoherence time, such that the phase reference is lost after m uses. We show that the optimal Gaussian encoding is generated by a Haar-random passive interferometer acting on pure product states. We upper- and lower-bound the optimal coherent state rate and exhibit a lower bound to the squeezed-coherent rate that, for the first time to our knowledge, surpasses any coherent encoding for m=1 and provides a considerable advantage with respect to the coherent-state lower bound for m>1.

Matias Bilkis

Real-time calibration of coherent-state receivers: learning by trial and error

We cast the discrimination of two coherent states of light as a reinforcement learning problem, in which an agent has to choose among a large number of configurations of a receiver composed of simple linear optics elements, on/off photodetectors and feedback, all within reach of current technology. The agent, though completely ignorant about the receiver, is asked to find its optimal configuration by repeating the experiment a finite number of times, based only on the information obtained from the photodetectors and on the correctness of its guess. Despite the fact that the quantum signals are not perfectly distinguishable and therefore an optimal configuration may lead to an incorrect guess (no reward), we construct agents that can both discover near-optimal configurations and achieve high real-time success rate, even in the presence of several noise-sources.

Marco Fanizza

Bounding the quantum capacity with flagged extensions

In this article we consider flagged extensions of channels that can be written as convex combinations of other channels, and find general sufficient conditions for the degradability of the flagged extension. An immediate application is a bound on the quantum and private capacities of any channel being a mixture of a unitary operator and another channel, with the probability associated to the unitary operator being larger than 1/2. We then specialize our sufficient conditions to flagged Pauli channels, obtaining a family of upper bounds on quantum and private capacities of Pauli channels. In particular, we establish new state-of-the-art upper bounds on the quantum and private capacities of the depolarizing channel, BB84 channel and generalized amplitude damping channel. Moreover, the flagged construction can be naturally applied to tensor powers of channels with less restricting degradability conditions, suggesting that better upper bounds could be found by considering a larger number of channel uses.

Maria Cristina Rodriguez

Quantum information spreading measured by out-of-time-order correlations with magnetic resonance

The development of quantum technologies requires reliable processing of quantum information on large quantum systems. This is highly challenging as quantum systems are more sensitive to perturbations with increasing system size. In the last years, out-of-time-order correlations (OTOC) have gained special interest for measuring sensitivity to perturbations of many-body systems. These OTOCs can be experimentally measured with time reversion of quantum evolutions, on which the reversion is considered perfect. However, in practice the time reversion always contains imperfections. We study the spreading of information from a local state by monitoring OTOC dynamics. We perform quantum simulations with solid-state Nuclear Magnetic Resonance.

Nikolai Miklin

A universal scheme for robust self-testing in the prepare-and-measure scenario

We consider the problem of certification of arbitrary ensembles of pure states and projective measurements solely from the experimental statistics in the prepare-and-measure scenario assuming the upper bound on the dimension of the Hilbert space. To this aim we propose a universal and intuitive scheme based on establishing perfect correlations between target states and suitably-chosen projective measurements. The method works in all finite dimensions and allows for robust certification of the overlaps between arbitrary preparation states and between the corresponding measurement operators. Finally, we prove that for qubits our technique can be used to robustly self-test arbitrary configurations of pure quantum states and projective measurements. These results pave the way towards practical application of the prepare-and-measure paradigm to certification of quantum devices.

Pierre-Emmanuel Emeriau

Quantum Advantage in Information Retrieval

Random access codes have provided many examples of quantum advantage in communication, but concern only one kind of information retrieval task. We introduce a related task - the Torpedo Game - and show that it admits greater quantum advantage than the comparable random access code. Perfect quantum strategies involving prepare-and-measure protocols with experimentally accessible three-level systems emerge via analysis in terms of the discrete Wigner function. The example is leveraged to an operational advantage in a pacifist version of the strategy game Battleship. We pinpoint a characteristic of quantum systems that enables quantum advantage in any bounded-memory information retrieval task. While preparation contextuality has previously been linked to advantages in random access coding we focus here on a different characteristic called sequential contextuality. It is shown not only to be necessary and sufficient for quantum advantage, but also to quantify the degree of advantage. For qutrit strategies we observe the strongest type of inconsistency with noncontextual hidden variables, revealing logical paradoxes with respect to those assumptions.

Richard Lopp

Quantum center of mass, gauges and quantum optics: The light-matter interaction in relativistic QI

We analyze in what regimes different degrees of approximation of light-matter interactions in quantum optics and relativistic quantum information are reasonable and in what cases they need to be refined to capture the features of the light-matter interaction. This is particularly important when considering the center of mass (COM) of the atom as a quantum system that can be delocalized over multiple trajectories. For example, we show that the simplest scalar-analogue model with a quantum COM fails to capture crucial Roentgen terms coupling COM and internal atomic degrees of freedom with each other and the field.

Jonatan B. Brask

Tight Bound on Finite-Resolution Quantum Thermometry at Low Temperatures

We investigate fundamental precision limits for thermometry on cold quantum systems, taking into account constraints due to finite measurement resolution. We derive a tight bound on the optimal precision scaling with temperature, as the temperature approaches zero. The bound demonstrates that under finite resolution, the variance in any temperature estimate must decrease slower than linearly.

Meet & Greet on Remo

Closing remarks

André M. Timpanaro

Landauer's principle at zero temperature

Landauer's bound relates changes in the entropy of a system with the inevitable dissipation of heat to the environment. The bound, however, becomes trivial in the limit of zero temperature. In this work we derive a stricter bound which remains non-trivial even at low temperatures. We consider the usual setup with a thermal environment at temperature T and the only extra information required to use this new bound is the dependence of the environment heat capacity with the temperature (nothing is said about the state of the system or the kind of system-environment interaction).

Philip Taranto

Exponential improvement for quantum cooling through finite memory effects

Practical implementations of quantum technologies require preparation of states with a high degree of purity or, in thermodynamic terms, very low temperatures. Given finite resources, the third law of thermodynamics prohibits perfect cooling; nonetheless, attainable upper bounds for the asymptotic ground-state population of a system repeatedly interacting with quantum thermal machines have been derived. These bounds apply within a memoryless (Markovian) setting, in which each refrigeration step proceeds independently of those previous. Here, we expand this framework to study the effects of memory on quantum cooling. By introducing a memory mechanism through a generalized collision model that permits a Markovian embedding, we derive achievable bounds that provide an exponential advantage over the memoryless case. For qubits, our bound coincides with that of heat-bath algorithmic cooling, which our framework generalizes to arbitrary dimensions. We lastly describe the adaptive stepwise optimal protocol that outperforms all standard procedures.

Tiago Debarba

Work Estimation and Work Fluctuations in the Presence of Non-Ideal Measurements

From the perspective of quantum thermodynamics, realisable measurements cost work, and result in measurement devices that are not perfectly correlated with the measured systems. We investigate the consequences for the estimation of work in non-equilibrium processes and in the fundamental structure of the fluctuations when one assumes that the measurements are non-ideal. We show that obtaining work estimates and their statistical moments at finite work cost implies an imperfection of the estimates themselves: more accurate estimates incur higher costs.

Hlér Kristjánsson

Resource theories of communication

A series of recent works has shown that placing communication channels in a coherent superposition of alternative configurations can boost their ability to transmit information. Instances of this phenomenon are the use of communication devices in a superposition of alterna- tive causal orders, and the transmission of information along a superposition of alternative trajectories. To shed light on these new types of communication protocols, we develop a general framework of resource theories of communication, formulating a minimal requirement for meaningful allowed operations on communication resources.

V. Vilasini

Analysing causal structures using Tsallis entropies

We analyse causal structures using Shannon and Tsallis entropies with and without post-selection. Without post-selection, Shannon entropies are known to have certain limitations for certifying non-classicality. We investigate whether Tsallis entropies can overcome these limitations and derive constraints on Tsallis entropies implied by a general causal structure before applying these to find new entropic inequalities for the Triangle causal structure. In the post-selected Bell causal structure, we find numerical evidence that Shannon and Tsallis entropic inequalities are insufficient for detecting non-classicality in the 2 input and 3 outcome case, in contrast to a known result for the 2 outcome case.

Awareness Session

Ethics in Quantum Research

Emma McKay (McGill University). Quantum tech has big ethical problems, which are also ecological and political. I'll talk about what makes an ethical system useful and consider our current systems in light of some case studies in quantum tech.

Meet & Greet on Remo