# Young IQIS 2020 - Young Italian Quantum Information Science Conference

**Monday, 28 September 2020 - Friday, 2 October 2020**

**Online event**

# Programme

# Table of contents

# Monday 28 September 2020

## Satellite Event: Tutorial Lecture by Laleh Memarzadeh (28 Sep 2020, 10:00-12:00)

Chairperson: Ugo Marzolino

| time | title |
|---|---|
| 10:00 | Satellite Event: Tutorial Lecture "Structure of Quantum Channels"<br>*Presenter: MEMARZADEH, Laleh (Sharif Universiy of Technology, Tehran)*<br>One of the most promising tasks of quantum information is establishment of secure and reliable quantum communication channels over distant nodes. Beside theoretical success in formalizing the role of quantum features of systems for communication, current technological progress supports practical implementation of communication protocols. However, the role of quantum channels in quantum information science and technology is not restricted to communication protocols. The most general form of evolution of quantum systems is described by a quantum channel or a completely positive trace preserving (CPTP) map. Analyzing the mathematical structure of the space of CPTP maps, not only deepens our understanding on the nature of quantum evolution, but also plays an important role in implementation of quantum information tasks. In this tutorial, after a short review on the role of quantum channels in communication, we review the convex structure of quantum channels as well as divisibility properties of quantum channels. We will discuss how such an abstract knowledge leads to practical applications such as quantum simulation. |

## Welcome (28 Sep 2020, 13:45-14:00)

Iris Agresti, Claudia Benedetti, Mario Collura, Ilaria Gianani, Ugo Marzolino, Francesco Pepe

## **Invited: Quantum Optics** (28 Sep 2020, 14:00-15:00)

Chairperson: Costanza Toninelli

time title

14:00 Structured glass for low power actuation of thermal phase shifters

*Presenter: ATZENI, Simone (Politecnico di Milano)*

Femtosecond laser micromachining (FLM) is a versatile technique that allows cost-effective and rapid fabrication of 3D photonic integrated circuits providing devices for various applications, ranging from lab-on-a-chip to quantum interferometry. Up to date, the possibility to reconfigure the operations performed by these circuits mainly relies on thermal phase shifters. However, the actuation of an integrated microheater requires several hundreds of milliwatts (around 600 mW) to induce a 2π phase shift in FLM devices operating at telecom wavelength, thus preventing the integration of more than a few microheaters on the same chip. Therefore, we devised a new FLM fabrication process, based on water-assisted-laser-ablation, able to reduce the power dissipation for a given phase shift of more than one order of magnitude, with no compromise either on the compactness or on the passive optical performance of the circuit. We realized Mach-Zehnder interferometers encompassing high-quality optical waveguides in aluminum borosilicate glass (0.29 dB/cm propagation losses and 0.27 dB/facet coupling losses at 1550 nm) and two different types of thermally insulating microstructures. In particular, isolation trenches on the sides of the heated photon path and bridge waveguides, structures in which the glass is ablated also under the optical path. As a result, interferometers featuring trenches show a reconfiguration period of 57 mW, whilst bridge waveguide ensures a reduction of the power dissipation required to induce a 2π phase shift down to 37 mW. In the end, we performed the same experimental measurements in a vacuum environment, demonstrating a further reduction in the required power dissipation when air is removed from the ablated regions. The advantages of structured devices are also underlined by performing thermal crosstalk measurements. These results will lead to an increase of the devices complexity attainable with FLM technology, opening new scenarios both in classical and quantum information applications.

14:15 Entanglement-based quantum key distribution using a deterministic quantum dot photon source

*Presenter: BASSO BASSET, Francesco (Sapienza University of Rome)*

Entanglement-based protocols for quantum key distribution (QKD) provide additional layers of security compared to single-photon prepare-and-measure approaches, despite presenting the challenge of a less immediate hardware implementation. As remarkable technical achievements have been used to demonstrate entanglement-based QKD over longer and longer distances [1], the main opportunity for further development is related to multiphoton emission. This is a fundamental limitation for state-of-the-art photon sources based on spontaneous parametric down-conversion, which can be solved using deterministic quantum emitters. Here we focus on semiconductor quantum dots, which can generate nearly on-demand photon pairs with record-low multiphoton emission [2] and Bell state fidelity currently up to 98% [3]. We experimentally demonstrate the viability of this technology in a realistic urban communication scenario [4]. We employ a modified asymmetric Ekert protocol and perform QKD comparing two choices of quantum channel: over a 250 m single-mode fiber and in free-space between two buildings across the campus of the Sapienza University of Rome. The key exchange is successfully performed with error rates of 3–4%, well below the protocol threshold, and with substantial violations of the Bell inequality. The results are discussed in relation to the technical solutions employed for transferring the signal and to the current state of development of the source. In this regard, an outlook is presented based on the latest and foreseen advances in source design that can lead to unprecedented pair emission rates and boost secure key exchange over long distances.

[1] Yin J., et al., Nature 582, 501–505 (2020).
[2] Schweickert L., et al., Applied Physics Letters 112, 093106 (2018).
[3] Huber D., et al., Physical Review Letters 121, 033902 (2018).
[4] Basso Basset F., Valeri M., et al., arXiv:2007.12727 (2020).

**14:30** Cross-Talk effects on conditional measurements

*Presenter: CHESI, Giovanni (Università degli Studi di Pavia)*

Photon-number resolving detectors have experienced a wide spread throughout the last decades and proved to be versatile for a large number of applications. In particular, Multi-Pixel Photon Counters (MPPC) have been shown to be promising for Quantum Optics applications [1,2,3]. Unfortunately, these detectors are typically affected by correlated noise, which is especially detrimental for the detection of quantum correlations. The most important source of correlated noise is the Optical Cross-Talk (OCT), i.e. a photon emitted by a decelerating photoelectron fires a neighboring pixel, thus providing a spurious count. We have recently shown [4;5;6;7] that a commercial class of MPPC, i.e. the silicon photomultipliers, allows to detect the nonclassicality of a conditional state even in the presence of the OCT. In particular, we generated a multimode twin-beam state and used the silicon photomultipliers to perform conditional measurements. We successfully revealed the sub-Poissonianity of the conditional state. However, as far as we know, a theoretical description of a conditional measurement in the presence of the OCT is still lacking. Here, we extend the model for the conditional measurements with photon counting introduced in [8] by including the effect of the OCT. We provide the statistics of the number of detected photons for the conditional state and retrieve the analytic expression of the related Fano factor.

[1] I. Afek et al., “Quantum state measurements using multipixel photon detectors,” Phys. Rev. A 79, 043830(1-6) (2009).
[2] D. A. Kalashnikov et al., “Measurement of two-mode squeezing with photon number resolving multipixel detectors,” Opt. Lett. 27, 14(2829-2831) (2012).
[3] G. Chesi et al., “Optimizing Silicon photomultipliers for Quantum Optics,” Sci. Rep. 9, 7433(1-12) (2019).
[4] G. Chesi et al., “Measuring nonclassicality with silicon photomultipliers,” Opt. Lett. 44, 6(1371-1374) (2019).
[5] G. Chesi et al., “Effects of nonideal features of silicon photomultipliers on the measurements of quantum correlations,” Int. J. Quantum Inf. 17, 1941012 (2019).
[6] G. Chesi et al., “Autocorrelation functions: a useful tool for both state and detector characterisation,” Quantum Meas. Quantum Metrol. 6, 1(1-6) (2019).
[7] M. Bondani et al., “Measuring nonclassicality of mesoscopic twin-beam states with Silicon Photomultipliers,” Proceedings 12, 48-52 (2019).
[8] A .Allevi et al., “Conditional measurements on multimode pairwise entangled states from spontaneous parametric downconversion”, EPL 92,1-6 (2010).

**14:45** Two-membrane cavity optomechanics

*Presenter: PIERGENTILI, Paolo (University of Camerino)*

The optomechanical behaviour of a driven high finesse Fabry-Pérot cavity containing two vibrating dielectric Si3N4 membranes will be presented. The presence of the second membrane inside the optical cavity enhances the optomechanical coupling making this system interesting to reach the strong-coupling regime [1-2]. Moreover, the presence of two optical resonators provides the opportunity to couple mechanical resonators with very similar frequencies. This pave the way to the realization of an efficient state transfer and even entanglement between the mechanical oscillators. Multi-element systems of micro/nano-mechanical resonators offer promising prospects for exploring multi-oscillators synchronization [3-5]. The first experimental characterization of the optical, mechanical, and especially optomechanical properties of a sandwich constituted of two parallel membranes within an optical cavity will be reported. We find that the optomechanical coupling strength is enhanced by constructive interference when the two membranes are positioned to form an inner cavity which is resonant with the driving field. Specifically, we determine a gain of □2.47 in the coupling strength of the relative mechanical motion with respect to the single membrane configuration [3]. Finally, the behaviour of the non-linear dynamics of such a system in a pre-synchronization regime where both large and small amplitude resonator motions are transduced in a nontrivial way by the non-linear response of the optical probe beam, will be discussed [5].

[1] J. Li, A. Xuereb, N. Malossi, and D. Vitali, J. Opt., 18, 084001, 2016
[2] J. Li, G. Li, S. Zippilli, D. Vitali, and T. Zhang, Phys. Rev. A., 95, 043819, 2017
[3] P. Piergentili, L. Catalini, M. Bawaj, S. Zippilli, N. Malossi, R. Natali, D. Vitali, and G. Di Giuseppe, New J. Phys., 20, 101001, 2018
[4] W. Li, P. Piergentili, J. Li, S. Zippilli, R. Natali, N. Malossi, G. Di Giuseppe, and D. Vitali, Phys. Rev. A, 101, 013802, 2020
[5] P. Piergentili, W. Li, R. Natali, N. Malossi, D. Vitali, and G. Di Giuseppe, in preparation

**Break (15:00-15:15)**

## Contributed: Quantum Metrology (28 Sep 2020, 15:15-16:15)

Chairperson: Marco G. Genoni

| time | title |
|---|---|
| 15:15 | Noisy quantum metrology enhanced by continuous nondemolition measurement<br>*Presenter: ROSSI, Matteo (University of Turku)*<br>In this work, we show that, by exploiting continuous quantum nondemolition measurement, it is possible to preserve quantum advantage in a frequency estimation (or magnetometry) measurement scheme even in the presence of independent dephasing noise, usually the most detrimental type of noise. We thus verify that such enhancement is preserved thanks to non-classical correlations, namely spin squeezing, which are dynamically generated by the measurement itself. Remarkably, our scheme does not require the preparation of any entangled, or non-classically correlated state of the probe: the probe is initialized in a classical coherent spin state and the resources required for the quantum enhancement are dynamically created during the conditional evolution. We moreover provide evidence that our results are robust and hold true in a wide range of noise intensities and even in the presence of inefficient measuring devices. |
| 15:23 | Continuous-time quantum walks in the presence of a quadratic perturbation<br>*Presenter: RAZZOLI, Luca (Università di Modena e Reggio Emilia)*<br>We address the properties of continuous-time quantum walks with Hamiltonians of the form $H= L + \lambda L^2$, being $L$ the Laplacian matrix of the underlying graph and being the perturbation $\lambda L^2$ motivated by its potential use to introduce next-nearest-neighbor hopping. We consider cycle, complete, and star graphs because paradigmatic models with low/high connectivity and/or symmetry. First, we investigate the dynamics of an initially localized walker. Then, we devote attention to estimating the perturbation parameter $\lambda$ using only a snapshot of the walker dynamics. Our analysis shows that a walker on a cycle graph is spreading ballistically independently of the perturbation, whereas on complete and star graphs one observes perturbation-dependent revivals and strong localization phenomena. Concerning the estimation of the perturbation, we determine the walker preparations and the simple graphs that maximize the Quantum Fisher Information. We also assess the performance of position measurement, which turns out to be optimal, or nearly optimal, in several situations of interest. Besides fundamental interest, our study may find applications in designing enhanced algorithms on graphs. |
| 15:30 | Super-resolution Optical Fluctuation Imaging—fundamental estimation theory perspective<br>*Presenter: KURDZIAŁEK, Stanisław (Faculty of Physics, University of Warsaw)*<br>We provide a rigorous quantitative analysis of super-resolution imaging techniques which exploit temporal fluctuations of luminosity of the sources in order to beat the Rayleigh limit. We define an operationally justified resolution gain figure of merit, that allows us to connect the estimation theory concepts with the ones typically used in the imaging community, and derive fundamental resolution bounds that scale at most as the fourth-root of the mean luminosity of the sources. We fine-tune and benchmark the performance of state-of-the-art methods, focusing on the cumulant based image processing techniques, taking into account the impact of limited photon number and sampling time. |
| 15:38 | Quantum multiphase estimation in an integrated photonic circuit<br>*Presenter: POLINO, Emanuele (La Sapienza)*<br>Quantum Metrology is one of the most important quantum technologies where quantum resources are exploited to enhance the estimation of unknown parameters [1]. In this context, since realistic scenarios generally involve more than one parameter, quantum multiparameter estimation is a central and very active research area. Nevertheless, in such relatively new field, several open questions are still present and experimental platforms able to perform multiparameter estimation protocols have to be developed. We realized a reconfigurable photonic integrated circuit, built through the femtosecond lase writing technique, able to perform simultaneous multiphase estimation with photonic quantum states. The circuit realizes a three arm interferometer and is highly tunable, so that the two independent phase shifts between the interfetometer's arms can be tuned. Firstly, we demonstrate quantum enhanced two-phases estimation by using two-photon probes [2]. Then we provide a demonstration of a Bayesian adaptive protocol able to saturate, in the limited data regime, the sensitivity bound (Cramer-Rao bound) on the estimation of the two phases when single photon probes are employed [3].<br><br>[1] E. Polino, M. Valeri, N. Spagnolo, and F. Sciarrino, AVS Quantum Science 2, 024703 (2020).<br>[2] E. Polino, M. Riva, M. Valeri, R. Silvestri, G. Corrielli, A. Crespi, N. Spagnolo, R. Osellame, and F. Sciarrino, Optica 6, 288 (2019).<br>[3] M. Valeri, E. Polino, D. Poderini, I. Gianani, G. Corrielli, A. Crespi, R. Osellame, N. Spagnolo, and F. Sciarrino, arXiv preprint arXiv:2002.01232 (2020). |

15:45 A machine learning approach to Bayesian parameter estimation

*Presenter: NOLAN, Samuel (QSTAR, INO-CNR and LENS)*

Bayesian estimation is a powerful theoretical paradigm for the operation of quantum sensors. However, the Bayesian method for statistical inference generally suffers from demanding calibration requirements, that have so far restricted its use to systems that can be explicitly modelled. In this theoretical study, we formulate parameter estimation as a classification task and use artificial neural networks to efficiently perform Bayesian estimation. We show that the network's posterior distribution is centred at the true (unknown) value of the parameter within an uncertainty given by the inverse Fisher information, representing the ultimate sensitivity limit for the given apparatus. When only a limited number of calibration measurements are available, our machine-learning based procedure outperforms naive calibration methods. Our machine-learning based procedure is model independent, and is thus well suited to a black box sensor where an explicit model is unavailable. Thus, our work paves the way for Bayesian quantum sensors that can take advantage of complex, potentially non-classical quantum states, which can significantly enhance the sensitivity of future devices.

15:52 Bayesian multiphase estimation at the Heisenberg limit

*Presenter: GEBHART, Valentin (QSTAR, CNR-INO and University of Napoli)*

Quantum (multi-)parameter estimation provides the central ingredient for many quantum technological tasks like, e.g., quantum computation or precision measurements. Previous work focussed mainly on single phase estimation at the fundamental limit, the Heisenberg limit, or on multiphase estimation at an optimal point. Here, we propose a quantum algorithm to measure d completely unknown phases and provide numerical evidence for Heisenberg limited precision of the algorithm. We show that the algorithm can outperform single phase estimation and discuss a possible quantum optical implementation.

16:00 Critical Quantum Metrology with a Finite-Component Quantum Phase Transition

*Presenter: FELICETTI, Simone (Istituto di Fotonica e Nanotecnologie, Consiglio Nazionale delle Ricerche IFN-CNR)*

Physical systems close to a quantum phase transition exhibit a divergent susceptibility, suggesting that an arbitrarily high precision may be achieved by exploiting quantum critical systems as probes to estimate a physical parameter. However, such an improvement in sensitivity is counterbalanced by the closing of the energy gap, which implies a critical slowing down and an inevitable growth of the protocol duration. In this contribution, we present different metrological protocols that exploit the superradiant phase transition of the quantum Rabi model, a finite-component system composed of a single two-level atom interacting with a single bosonic mode. 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.

16:07 Discrimination of Ohmic thermal baths by quantum dephasing probes

*Presenter: CANDELORO, Alessandro*

The discrimination of structured baths at different temperatures by dephasing quantum probes is studied. The exact reduced dynamic is derived, and the minimum error probability is evaluated by three different kinds of quantum probes, namely a qubit, a qutrit, and a quantum register made of two qubits. The results indicate that dephasing quantum probes are useful in discriminating low values of temperature and that lower probabilities of error are achieved for intermediate values of the interaction time. A qutrit probe outperforms a qubit one in the discrimination task, whereas a register made of two qubits does not offer any advantage compared to two single qubits used sequentially.

**Break (16:15-16:30)**

## Invited: Atoms and Molecules (28 Sep 2020, 16:30-17:15)

Chairperson: Maria Bondani

| time | title |
|---|---|
| 16:30 | Integrated Organic Molecules for Quantum Technologies<br>*Presenter: COLAUTTI, Maja (CNR-Ino - European Laboratory for Non-Linear Spectroscopy (LENS))*<br>The realization of a robust and scalable nanophotonic platform which efficiently integrates quantum emitters as on-demand sources of non-classical light is crucial to the successful development of photonic quantum technologies. However, conventional strategies to on-chip integration, based on lithographic processes in semiconductors, typically introduce dephasing effects which broaden the transition linewidth of the emitter and are detrimental for its coherence properties. Moreover, such fabrication techniques are intrinsically limited to planar geometries and in this sense are difficult to scale up to a big number of integrated emitters. In the present contribution we demonstrate an alternative platform based on molecules that preserve near-Fourier-limited fluorescence even when embedded in polymeric photonic structures [1]. Deterministic integration is achieved in three-dimensions via direct laser writing (DLW) around selected molecular emitters, with a fast, inexpensive and scalable fabrication process. In particular, organic molecules of dibenzoterrylene (DBT) are embedded in anthracene (Ac) nanocrystals (NCs), which have shown photostable single-photon emission, near to lifetime-limited linewidths at 3K [2], and are especially suitable for the integration in polymeric devices. We integrate DBT:Ac NCs via DLW on different substrates and at variable heights in different polymeric designs. Enhanced light extraction is achieved in a micro-dome solid-immersion-lens, reporting unprecedented detected count rates for a single cold molecule and efficient coupling to a single-mode fiber. The proposed technology may represent an important step in the integration of single emitters into robust quantum protocols based on molecules, including arrays of indistinguishable single-photon sources. In this latter merit, we will also discuss the possibility of using an all-optical approach to independently shift the transition frequency of individual emitters and bring them into resonance, with spacial resolution at the micron level and maintaining the coherent spectral properties [3].<br><br>[1] M. Colautti et al., Adv. Quantum Technol., (2020) doi:10.1002/qute.202000004<br>[2] S. Pazzagli et al., ACSNano 12, 4295–4303 (2018).<br>[3] M. Colautti et al., Under Review |
| 16:45 | Adiabatic Quantum Operations with UltraStrongly Coupled Artificial Atoms<br>*Presenter: GIANNELLI, Luigi (Dipartimento di Fisica e Astronomia "Ettore Majorana", Universitá di Catania)*<br>Ultrastrong coupling (USC) between light and matter has been recently achieved in architectures of solid state artificial atoms coupled to cavities. Such architectures may provide new building blocks for quantum state processing, where ultrafast operations could be performed. However faster dynamics has a cost. Indeed USC breaks the symmetry associated with the conservation of the number of excitations, leading to a series of new physical effects of great fundamental interest but detrimental for quantum state processing. In particular the highly entangled nature of the eigenstates, dressed by a potentially very large number of virtual photons, leads to leakage of excitation via the dynamical Casimir effect (DCE) and via decay. In this work we analyze quantum operations between two artificial atoms ultrastrongly coupled to a cavity, operating as a virtual bus. We show that an adiabatic protocol similar to STIRAP may overcome the problem of leakage. Ideally the cavity is never populated and thus it is expected to greatly reduce the impact of DCE and decay. We show that high fidelity operations can be performed for moderate couplings in the USC regime and fidelities higher than the ones obtained in the strong coupling regime (SC, where the rotating wave approximation holds) can be obtained. Moreover, optimal control theory allows for properly crafted controls that extend the high fidelity region to even larger couplings. The protocol is extremely robust agaist DCE, in the absence of decoherence yields almost 100% fidelity for remote state transfer and multiqubit entanglement generation. It is also resilient to decay due to leakage from the cavity, which is the main decoherence mechanism for present USC architectures. In this more realistic scenario it is seen that for larger coupling (entering the deep strong coupling regime) the fidelity decreases due to the interplay between decoherence and DCE. Our results suggest that adiabatic manipulations, may be a promising tool for quantum state processing in the USC regime. |

17:00 **Anyonic molecules in atomic fractional quantum Hall liquids: a quantitative probe of fractional charge and anyonic statistics**

*Presenter: MUNOZ DE LAS HERAS, Alberto (University of Trento)*

We study the quantum dynamics of massive impurities embedded in a strongly interacting two-dimensional atomic gas driven into the fractional quantum Hall (FQH) regime under the effect of a synthetic magnetic field. For suitable values of the atom-impurity interaction strength, each impurity can capture one or more quasi-hole excitations of the FQH liquid, forming a bound molecular state with novel physical properties. An effective Hamiltonian for such molecules is derived within the Born-Oppenheimer approximation, which provides renormalized values for the effective mass, charge and statistics of such anyonic molecules by combining the finite mass of the impurity and the fractional charge and anyonic statistics of the quasi-holes. The anyonic statistics is shown to provide a long-range Aharonov-Bohm-like interaction between molecules. The resulting relative phase of the direct and exchange scattering channels can be thus extracted from the angular position of the interference fringes in the scattering cross section of a pair of colliding molecules. Different configurations providing direct and quantitative insight on the fractional charge and the anyonic statistics of quasi-hole excitations in FQH liquids are highlighted for both cold atoms and photonic systems.

**Break (17:15-17:30)**

## Career Panel: Academy (28 Sep 2020, 17:30-18:30)

Moderator: Rosario Fazio

| time | title |
|---|---|
| 17:30 | Career panel: Academy<br>Panelists:<br><br>Marcello Dalmonte (ICTP)<br><br>Giovanna Morigi (Universität des Saarlandes)<br><br>Saverio Pascazio (Università di Bari)<br><br>Fabio Sciarrino (La Sapienza Università di Roma) |

**Break** (18:30-19:30)

## Beers and Posters: Day 1 (28 Sep 2020, 19:30-21:00)

time title

19:30 P1

### Variational counterdiabatic driving of the ferromagnetic p-spin model

*Presenter: PASSARELLI, Gianluca (University of Naples)*

In adiabatic quantum computation, the goal is to find the ground state of a many-body Hamiltonian starting from the simple ground state of a transverse field potential. A fast evolution time renders the system robust against decoherence and thermal noise but can cause diabatic transition towards excited states. Adding a counterdiabatic (CD) potential to the original Hamiltonian can suppress Landau-Zener excitations and drive the system towards the correct target state.

The exact general form of the CD driving operator, derived by Berry [1], is useless for all practical purposes as it cannot be implemented on physical processors. On the other hand, Sels and Polkovnikov [2] have shown that there exists a variational formulation of the CD problem that allows one to build approximate, experimentally-viable CD operators. For many-body systems, this can be done using a series expansion of the CD operator, the nested commutator (NC) ansatz, that can be easily engineered using Floquet pulses [3].

We tested the variational approach to CD driving for the ferromagnetic p-spin model [4]. Despite its apparent simplicity, this model is often used to benchmark the performance of quantum annealing. In our work, we show that the NC ansatz can be successfully used to improve the
annealing performances of this fully-connected system, although its efficiency is bound to decrease in the thermodynamic limit. In addition, we show that it is possible to use another ansatz for $p = 3$, which we named cyclic ansatz (CA), that allows us to have optimal fidelity even for extremely short dynamics, independently of the system size. We analyze generalized p-spin systems to get a further insight into our ansatz.

[1] M. V. Berry, “Transitionless quantum driving”, Journal of Physics A, 42, 36 (2009)
[2] D. Sels and A. Polkovnikov, “Minimizing irreversible losses in quantum systems by local counterdiabatic driving”, PNAS May 16, 114 (20) (2017)
[3] P. W. Claeys, M. Pandey, D. Sels, and A. Polkovnikov, “Floquet-Engineering Counterdiabatic Protocols in Quantum Many-Body Systems”, Phys. Rev. Lett. 123, 090602 (2019)
[4] G. Passarelli, V. Cataudella, R. Fazio, and P. Lucignano, “Counterdiabatic driving in the quantum annealing of the p-spin model: A variational approach”, Phys. Rev. Research 2, 013283 (2020)

19:30 **P2** Irreversibility in unitary quantum homogeneisation: Theory and Experiment

*Presenter: REBUFELLO, Enrico (Istituto Nazionale di Ricerca Metrologica and Politecnico di Torino)*

Is it possible to reconcile irreversibility and a time-reversal symmetric theory such as quantum mechanics (QM)? In this work, we consider a specific type of constructor-based irreversibility, which allows a generalization of the classical irreversibility based on the second law of thermodynamics. Let the task T be the specification of a physical transformation on qubits which brings a quantum state s to another quantum state f: T={s -> f}. Its transpose is: R={f -> s}. Then, a constructor for the task T is a physical system that enables T to occur on the substrates without undergoing any net change in its ability to do it again. Thus, we can say that a task is possible if the laws of physics do not put any constraint on the accuracy with which it can be performed by a constructor. It is impossible otherwise. Constructor-based irreversibility, then, consists in the fact that while the task T is possible, its transpose R is not. A classical example of this may be that a cycle (a constructor) that converts completely work into heat is possible but a cycle that performs the transpose task is not. For a constructor, this is equivalent to say that the constructor of the transpose task has lower accuracy than the one for the straight task, i.e. the distance between the task goal and the constructor output is greater in the transpose case with respect to the straight one. Our study focuses on a quantum model for constructor-based irreversibility based on homogenisation machines. An homogenisation machine implements a task T={s -> f} by having the initial qubit in the pure state s undergo a series of partial swaps with an environment of qubits in the mixed state f. The transpose task R={f -> s}, then, is implemented by having a mixed state f undergoing the series of partial swaps with an environment in the pure state s. In our implementation, we consider two states: a pure state s = |0><0| and a maximally mixed state f=0,5(|0><0|+|1><1|) and we compare the two cases of an incoming state s (pure to mixed task T) and of an incoming task f (mixed to pure task R). In order to compare the two tasks, we measure the accuracy of each machine in performing the task by computing the error E, defined as one minus the Fidelity between the output state and the goal of the task (f for the pure-to-mixed task and s for the mixed-to-pure task). In our setup, single photons are generated at 1550 nm by a low-noise heralded single photon source and sent to a 1x4 fiber optical switch which addresses them to four different optical paths, one for the “system” and three for the environment. The photon are prepared in the appropriate state and connected to a cascade of three consecutive fiber beam splitters (FBS, all either 50:50, 90:10 or 75:25) implementing subsequent partial swaps between the photons. Finally, the four outputs are sent to single-photon avalanche diodes, whose outputs are addressed to proper time-tagging electronics. Our preliminary results show that the pure-to-mixed task has a greater accuracy than the mixed-to-pure one, i.e., the error on the final state is greater in the mixed-to-pure case with respect to the pure-to-mixed one, in accordance to the theory.

19:30 **P3** Memory kernel and Divisibility of Gaussian Collisional Models

*Presenter: RAMIREZ CAMASCA, Rolando (University of Sao Paulo)*

Memory effects in open systems dynamics have been the subject of significant interest in the last decades. Methods quantifying this effect, however, are often difficult to compute and lack analytical insight. With this in mind, we consider Gaussian collisional models, where non-Markovianity is introduced by means of interactions between neighboring environments. We show that the dynamics can be cast in terms of a Markovian Embedding of the covariance matrix, which yields closed form expressions for the memory kernel and the CP-divisibility monotone. Our results aim to help understand the intricate mechanisms behind memory effects in the quantum domain.

[1] https://arxiv.org/abs/2008.00765

19:30 **P4** Detection of virtual photons in superconducting architectures

*Presenter: RAJENDRAN, Jishnu (Università degli Studi di Catania)*

Micro/nano-fabrication techniques have recently allowed producing quantum devices displaying ultra-strong coupling (USC) of radiation and matter. In this non-perturbative regime, distinctive phenomena emerge, as the highly entangled ground state involving many-photon states of the field. These ground-state virtual photons (VPs) cannot be revealed by standard photodetection since the ground-state does not decay. Several works [1-6] have proposed that VPs in USC solid-state devices can be converted to real photons using architectures with three-level artificial atoms (AAs). In this enlarged Hilbert space, appropriate classical control drives may induce leakage from the Rabi subspace which marks the presence of VPs. The works [1-6] consider different control protocols, namely, AC continuous pumping of photons with dynamical Casimir effect(DCE) [1], spontaneous emission pumping in Lambda scheme [2], Raman oscillations with two-tone pulses [3] and STIRAP in Lambda [4,5] and Vee [5] scheme, and stimulated emission, also implemented by a two-tone control field in Lambda scheme[6]. Notwithstanding having been subject of many investigations, such a population of virtual excitations remains still unobserved. The aim is of this work is to understand if experimental progress can be made in the detection of ground state photons with controlled three-level atom structures. To this end, we study a model integrating the various conversion protocols as mentioned above[1-6] and the detection steps, and with optimal control theory(OCT) to find optimal conditions for the efficient detection of VPs. Further, open systems effects have to be accounted for, since they may impact in particular on the fully coherent protocols [3,4,5].

[1] Carusotto et al, Phys. Rev. A 85, 023805 (2012)
[2] R. Stassi et al., Phys. Rev. Lett. 110, 243601 (2013)
[3] J.F. Huang and C.K. Law Phys. Rev. A 89, 033827 (2014)
[4] G. Falci et al., Fortschr. Phys 65, 1600077 (2017)
[5] Di Stefano et al, New J. Phys. 19, 053010 (2017)
[6] G. Falci et al., Sci. Rep. 9, 9249 (2019)

19:30 **P5** A Quantum Phase Estimation Algorithm with Gaussian Spin States

*Presenter: PEZZÉ, Luca*

Quantum phase estimation (QPE) is a most important subroutine in quantum computation. In general applications, however, current QPE algorithms either suffer an exponential time overload or require a set of, notoriously quite fragile, GHZ or NOON states. These limitations have prevented so far the demonstration of QPE beyond proof-of-principles. I present a new QPE algorithm that scales linearly with time and is implemented with a cascade of Gaussian spin states (GSS). GSS are renownedly resilient and have been created experimentally in a variety of platforms, with hundreds of ions up to millions of cold neutral atoms.The protocol achieves a QPE sensitivity overcoming previous bounds, including those obtained with GHZ and NOON states, and is robustly resistant to several sources of noise and decoherence. This paves the way toward the realistic quantum advantage demonstration of the quantum phase estimation.

19:30 **P6** Quantum correlations in a gravitational classical-channel model

*Presenter: ROCCATI, Federico (UNIPA)*

In models where gravity is mediated by a quantum field, gravitational interaction between two masses is accompanied by generation of entanglement. Gravitational interaction can yet be reproduced also by gravitational decoherence models where interaction is treated as a classical channel with no entanglement generation [1,2]. Here, we show that, despite the absence of entanglement, such a classical model entails creation of quantum correlations in the form of discord. Starting from a (fully classical) two-mode coherent state of two masses, we show that discord is generated reaching a universal asymptotic value, which can be worked out in a simple analytic form.

[1] D. Kafri, J. M. Taylor, and G. J. Milburn, New J. Phys. 16, 065020 (2014)
[2] J.L. Gaona-Reyes, M. Carlesso and A. Bassi, arXiv:2007.11980

19:30 **P7** Certification of incomaptible measurements and entangled subspaces using quantum steering

*Presenter: SARKAR, Shubhayan (Centre for Theoretical Physics, Polish Academy of Sciences)*

In recent times, nonlocality has been extensively explored for various device-independent certification tasks. Despite the success of these certification schemes towards verifying huge class of states, the avenue for certification of measurements is not well explored. It remains a highly nontrivial problem to propose a device independent scheme which could certify arbitrary pairs of incompatible measurements. Here we address this problem and propose a one-sided device independent protocol which could certify arbitrary d-outcome incompatible measurements along with entangled subspaces of local dimension $d$. We characterize the class of measurements which be used to certify the maximally entangled state of local dimension d. We find the robustness of our self-testing statement for a large class of incompatible measurements using a new analytical technique which might be helpful to find robustness bounds for various other self-testing statements. We further find a new steering inequality which can be used to self-test d dimensional schmidt states.

19:30 **P8** Entanglement witnesses: overview of the technique and a new construction

*Presenter: SCALA, Giovanni (BA)*

Given a quantum state, is not always possible to ascertain if it is entangled or separable. In this talk we show how to construct a new criterion for the separability as a powerful tool for entanglement detection based on the correlation tensor.

19:30 **P9** Persistence of Topological Phases in Non-Hermitian Quantum Walks

*Presenter: MITTAL, Vikash (Indian Institute of Science Education & Research (IISER) Mohali)*

Discrete-time quantum walks (DTQWs) are known to exhibit exotic topological states and phases. Physical realization of quantum walks in a noisy environment may destroy these phases. We investigate the behavior of topological states in quantum walks in the presence of a lossy environment. The environmental effects in the quantum walk dynamics are addressed using the non-Hermitian Hamiltonian approach. We show that the topological phases of the quantum walks are robust against moderate losses. The topological order in one-dimensional (1D) split-step quantum walk persists as long as the Hamiltonian is $\mathcal{PT}$-symmetric. Although the topological nature persists in two-dimensional (2D) quantum walks as well, the $\mathcal{PT}$-symmetry has no role to play there. Furthermore, we observe the noise-induced topological phase transition in two-dimensional quantum walks.

19:30 **P10** In situ thermometry of a cold Fermi gas via dephasing impurities

*Presenter: MITCHISON, Mark (Trinity College Dublin)*

The precise measurement of low temperatures is a challenging yet fundamental task for quantum science. In particular, in-situ thermometry of cold atomic systems is highly desirable due to their potential for quantum simulation. I will present some of our recent work [1] showing that the temperature of a non-interacting Fermi gas can be accurately inferred from the non-equilibrium dynamics of impurities immersed within it, using an interferometric protocol and established experimental methods. Adopting tools from the theory of quantum parameter estimation, we show that our proposed scheme achieves optimal precision in the experimentally relevant temperature regime for degenerate Fermi gases [2]. We also discover an intriguing trade-off between measurement time and thermometric precision that is controlled by the impurity-gas coupling, with weak coupling leading to the greatest sensitivities. This is explained as a consequence of the slow decoherence associated with the onset of the Anderson orthogonality catastrophe, which dominates the gas dynamics following its local interaction with the immersed impurity.

[1] M. T. Mitchison, T. Fogarty, G. Guarnieri, S. Campbell, T. Busch and J. Goold, Phys. Rev. Lett. 125, 080402 (2020).
[2] M. Cetina et al., Science 354, 96 (2016).

19:30 **P11** Joint measurement of non-classical correlations

*Presenter: MATSUYAMA, Kengo (Hiroshima university)*

We have experimentally performed joint measurements of the four polarization orientations that maximally violate a Bell's inequality. The joint statistical distributions directly obtained with the joint measurements depend on the measurement uncertainty trade-off between the two complementary polarizations measured for each photon. Our experimental results show that the Cirel'son bound is the limit beyond which the measurement uncertainties would not be sufficient to keep the outcome statistics positive.

19:30 **P12** Dark Soliton Qudits: A novel Quantum Information Platform in Bose-Einstein condensates

*Presenter: SHAUKAT, Muzzamal (Instituto de Telecomunicacoes, Lisbon, Portugal)*

We study the possibility of using dark solitons in quasi-one-dimensional Bose-Einstein condensates to produce two-level or three-level systems (qudits) by exploiting the intrinsic nonlinear and coherent nature of the matter waves. We calculate the soliton spectrum and the conditions for a qudit to exist. We also compute the coupling between the phonons and the solitons and investigate the emission rate of the qudit in that case. Remarkably, the qubit lifetime is estimated to be of the order of a few seconds, being only limited by the dark-soliton “death” due to quantum evaporation.

19:30 **P13** Genuinely entangled, stabilised subspaces

*Presenter: MAKUTA, Owidiusz (Centre for Theoretical Physics, Polish Academy of Sciences)*

The stabilizer formalism has been developed as a convenient way to describe quantum correction codes, however its utility does not end there. In our study we present a new procedure that one can use to identify a genuinely entangled subspace that is stabilised by some stabilizer. We use this new procedure to derive a bound on the dimension of a stabilised, genuinely entangled subspace. Then, to show that this bound can be saturated, we present an example of such a subspace of maximal dimension and through the violation of a Bell inequality we show that this subspace can be self-tested.

19:30 **P14** Witnessing non-Markovian effects of quantum processes through Hilbert-Schmidt speed

*Presenter: KHAZAEI SHADFAR, mahshid*

Non-Markovian effects can speed up the dynamics of quantum systems while the limits of the evolution time can be derived by quantifiers of quantum statistical speed. We introduce a witness for characterizing the non-Markovianity of quantum evolutions through the Hilbert-Schmidt speed (HSS), which is a special type of quantum statistical speed. This witness has the advantage of not requiring diagonalization of evolved density matrix. Its sensitivity is investigated by considering several paradigmatic instances of open quantum systems, such as one qubit subject to phase-covariant noise and Pauli channel, two independent qubits locally interacting with leaky cavities, V-type and \lambda-type three-level atom (qutrit) in a dissipative cavity. We show that the proposed HSS-based non-Markovianity witness detects memory effects in agreement with the well-established trace distance-based witness, being sensitive to system-environment information backflows.

19:30 P15

### Variational neural network ansatz for steady-states in open quantum systems

*Presenter: VICENTINI, Filippo (EPFL)*

The state of a Markovian open quantum system is completely determined by its density matrix which evolves according to a Lindblad master equation. When the system is composed by many interacting particles, the complexity arising from the many-body problem merges with the necessity to represent mixed states. In this work we exploit a variational ansatz described by a neural network to represent a generic nonequilibrium density matrix. By deriving a variational principle, we show that it is possible to define an iterative procedure where the network parameters are varied in order to minimize a cost function quantifying the distance from the asymptotic steady-state. Such a procedure, similar in spirit to supervised learning, can be performed efficiently by means of a Montecarlo sampling of the cost function. As a first application and proof-of-principle, we apply the method to the dissipative quantum transverse Ising model.

19:30 P16

### Distillation of Genuine Tripartite Quantum Steering

*Presenter: GUPTA, Shashank (S. N. Bose National Centre for Basic Sciences)*

Motivated from the work on distillation of Einstein-Podolsky-Rosen steering by Nery et al, we present a distillation scheme that extracts perfect genuinely steerable assemblages of GHZ/W type from the 'N' partly genuinely steerable assemblages of GHZ/W type by applying free operations. We first introduce free operations in the context of genuine tripartite steering and show that 2W-LOCC and 1W-LOCC operations do not create genuine steering in one-sided device independent (1SDI) and two-sided-device-independent (2SDI) scenario respectively. Our distillation protocol works in 1SDI as well as 2SDI scenario when the input resource is of GHZ type. When the input resource is of W type, distillation is possible only for the 1SDI scenario. This provides a useful scheme for distinguishing two kind of genuinely steerable correlations in tripartite scenario. Later, we illustrate steering distillation of GHZ/W type in n-partite scenario using our protocol.

19:30 P17

### Localization effects in the disordered two-dimensional Bose-Hubbard-model

*Presenter: GEIßLER, Andreas (School of Physics and Astronomy, University of Nottingham)*

Some experiments already have shown signatures of many-body localization (MBL) in the disordered Bose-Hubbard model in one and two dimensional ultra cold atomic lattice gases [1] as well as the related superfluid to Bose-glass transition in three dimensions for moderate disorder [2]. A proper theoretical understanding of the MBL phenomenon depends on knowledge about the full eigenstate spectrum. Therefore, commonly used exact numerical studies have been limited to small system sizes. In contrast, the related Bose-glass phase can already be understood via the ground state. To obtain beyond mean-field insight into the full fluctuation spectrum we use the fluctuation operator expansion method [3], which also incorporates effects of entanglement. This way, we can perform a scaling analysis of both localization phenomena within a single framework. With the collection of obtained critical points, we are able to map out a phase diagram showing the superfluid to Bose-glass transition in the ground state as well as the presence of a mobility-edge in the corresponding many-body excitations.

[1] C. D'Errico et al., PRL 113, 095301 (2014); J.-y. Choi et al., Science 352, 1547 (2016)
[2] C. Meldgin et al., Nature Physics 12, 646 (2016)
[3] A. Geißler et al., PRA 98, 063635 (2018)

19:30 P18

### Machine learning non-Markovian quantum dynamics

*Presenter: FILIPPOV, Sergey (Moscow Institute of Physics and Technology, Steklov Mathematical Institute of Russian Academy of Sciences)*

Machine learning methods have proved to be useful for the recognition of patterns in statistical data. The measurement outcomes are intrinsically random in quantum physics, however, they do have a pattern when the measurements are performed successively on an open quantum system. This pattern is due to the system-environment interaction and contains information about the relaxation rates as well as non-Markovian memory effects. Here we develop a method to extract the information about the unknown environment from a series of projective single-shot measurements on the system (without resorting to the process tomography). The method is based on embedding the non-Markovian system dynamics into a Markovian dynamics of the system and the effective reservoir of finite dimension. The generator of Markovian embedding is learned by the maximum likelihood estimation. We verify the method by comparing its prediction with an exactly solvable non-Markovian dynamics. The developed algorithm to learn unknown quantum environments enables one to efficiently control and manipulate quantum systems.

19:30 P19

### Going beyond Local and Global approaches for localized thermal dissipation

*Presenter: FARINA, Donato (Scuola Normale Superiore di Pisa)*

Identifying which master equation is preferable for the description of a multipartite open quantum system is not trivial and has led in the recent years to the 'local vs. global debate' in the context of Markovian dissipation. We treat here a paradigmatic scenario in which the system is composed of two interacting harmonic oscillators A and B, with only A interacting with a thermal bath - collection of other harmonic oscillators - and we study the equilibration process of the system initially in the ground state with the bath finite temperature. We show that the completely-positive (CP) version of the Redfield equation obtained using coarse-grain and an appropriate time-dependent convex mixture of the local and global solutions give rise to the most accurate CP approximations of the whole exact system dynamics, i.e. both at short and at long time scales, outperforming the local and global approaches.

19:30 P20 **Resolution of incoherent sources beyond the Rayleigh limit by array homodyning**

*Presenter: DATTA, Chandan (Centre of New Technologies, University of Warsaw)*

Resolving the separation between the incoherent point sources is one of the important problems in optical imaging. The most conventional direct imaging approach is limited by the so-called Rayleigh criterion, which restricts the resolution of two point sources if their diffraction patterns overlap significantly. Here, we explore the advantage of the array homodyning in resolving the separation between two incoherent point sources well below the Rayleigh limit. We approach the resolution problem using the well-defined notion of the Fisher information. Remarkably, in the sub-Rayleigh regime, we show that we can surpass the conventional resolution limit with a sufficiently high signal-to-noise ratio. Moreover, for small separation, it is enough to inspect a single spatial mode of light as it contains most of the information. In addition, we provide an algorithm to estimate the separation between two point sources without any prior knowledge about their spatial distribution. The algorithm is supported by a Monte-Carlo simulation.

19:30 P21 **Fermionic versus bosonic behavior of confined Wigner molecules**

*Presenter: CUESTAS, Eloisa (National Council of Scientific Research of Argentina and National University of Cordoba)*

We assess whether a confined Wigner molecule constituted by 2N fermions behaves as N bosons or 2N fermions. Following the work by Law [Phys. Rev. A 71, 034306 (2005)] and Chudzicki et al. [Phys. Rev. Lett. 104, 070402 (2010)] we discuss the physical meaning and the reason why a large amount of entanglement is needed in order to ensure a bosonic composite behavior. By applying a composite boson ansatz, we found that a Wigner molecule confined in a two-dimensional trap presents a bosonic behavior induced by symmetry. The two-particle Wigner molecule ground state required by the composite boson ansatz was obtained within the harmonic approximation in the strong interacting regime. Our approach allows us to address few-particle states (widely studied within a variety of theoretical and numerical techniques) as well as a large number of particles (difficult to address due to computational costs). For a large number of particles, we found strong fermionic correlations exposed by the suppression of particle fluctuations. For a small number of particles, we show that the wave function calculated within the composite boson ansatz captures the Friedel-Wigner transition. The latter is shown in a regime in which strong correlations due to the Pauli exclusion principle arise; therefore, we conclude that the coboson ansatz reproduces the many-particle physics of a confined Wigner molecule, even in the presence of strong deviations of the ideal bosonic behavior due to fermionic correlations.

19:30 P22 **Efficiently simulable Multipartite Collision Model reproducing any Markovian master equation**

*Presenter: CATTANEO, Marco (IFISC (CSIC-UIB) and University of Turku)*

We introduce the Multipartite Collision Model to simulate the Markovian dynamics of any multipartite open quantum system by decomposing the system-environment interaction into elementary collisions between subsystems and ancillae, thus providing a simple decomposition in terms of elementary quantum gates for quantum computation. The generality of the model allows for the study of any possible Markovian global and local master equation in the presence of any kind of bath at any temperature, and makes it particularly suitable to address scenarios in which the fundamental interaction and energy exchange between subsystems and environment takes on great importance, e.g. in quantum thermodynamics. Moreover, we develop a method to estimate an analytical error bound for any repeated interactions model, and we use it to show that the error of the Multipartite Collision Model displays an optimal behavior. Finally, we proof that the Multipartite Collision Model is efficiently simulable on a quantum computer according to the dissipative quantum Church-Turing theorem.

19:30 **P23** Storage and retrieval of microwave pulses with molecular spin ensembles

*Presenter: BONIZZONI, Claudio (Istituto Nanoscienze CNR - Sezione S3 di Modena)*

Electronic spin degrees of freedom provided by spin ensembles have been efficiently exploited into circuit quantum electrodynamics architectures based on microwave devices and resonators at low temperature. Molecular spins have recently emerged as a new class of quantum systems whose electronic and nuclear spin states and their related quantum features can be tailored synthetically. Different strategies for encoding quantum information with molecular ensembles or single molecules have been developed and experimentally proved. Moreover, the coherent coupling with microwave photons have been recently successfully achieved with transition metal-based oxovanadium(IV) complexes [1,2] as well as with organic radicals [3,2] embedded into planar resonant geometries, paving the way for the integration of molecular spin ensembles into microwave quantum architectures. However, along this line, optimal experimental conditions and protocols (i.e. pulse sequences) to efficiently address the molecular spins still need to be found. In this work we test single crystals and solid dispersions of diluted oxovanadium tetraphenyl porphyrin (VO(TPP)) as prototypical molecular spin ensembles for the storage and retrieval of microwave pulses when embedded into planar superconducting microwave resonators at low temperature (2K) [4]. We first measure the (Hahn-echo) memory time and the Rabi Oscillations of the samples. We then test two Dynamical Decoupling sequences: the Carr-Purcell-Meiboom-Gill and the Uhrig Dynamical Decoupling. Both the sequences are found to enhance the memory time of the crystal samples up to three times after the application of a low number (3,4) of $\pi$ pulses, reaching up to 3 μs. We then successfully store and retrieve into the ensembles trains of up to 5 small pulses and we show that individual control on such excitations can be achieved. Our proof-of-principle results demonstrate the memory capabilities of molecular spin ensembles when embedded into quantum circuits [4].

[1] C. Bonizzoni, A. Ghirri, M. Atzori, L. Sorace, R. Sessoli and M. Affronte, Sci. Rep. 7, 13096 (2017)
[2] C. Bonizzoni, A. Ghirri and M. Affronte, Adv. Phys. X 3, 1435305 (2018)
[3] A. Ghirri, C. Bonizzoni, F. Troiani, N. Buccheri, F. Beverina, A. Cassinese and M. Affronte, Phys. Rev. A 93, 063855 (2016)
[4] C. Bonizzoni, A. Ghirri, F. Santanni, M. Atzori, L. Sorace, R. Sessoli and M. Affronte, NPJ Quantum Inf. 6, 68 (2020)

19:30 **P24** Generating and detecting bound entanglement in two-qutrits using a family of indecomposable positive maps

*Presenter: BHATTACHARYA, Bihalan (S. N. Bose National Centre for Basic Sciences)*

The problem of bound entanglement detection is a challenging aspect of quantum information theory for higher dimensional systems. Here, we propose an indecomposable positive map for two-qutrit systems, which is shown to detect a class of positive partial transposed (PPT) entangled states. A corresponding witness operator is constructed and shown to be weakly optimal and locally implementable. Further, we perform a structural physical approximation of the indecomposable map to make it a completely positive one, and find a new PPT entangled state which is not detectable by certain other well-known entanglement detection criteria.

# Wednesday 30 September 2020

## Invited: Quantum Protocols (30 Sep 2020, 14:00-15:00)

Chairperson: Paola Verrucchi

| time | title |
|---|---|
| 14:00 | Achieving Heisenberg scaling with maximally entangled states: an analytic upper bound for the attainable root mean square error<br>*Presenter: BELLIARDO, Federico (Scuola Normale Superiore, Pisa)*<br>In this talk we explore the possibility of performing Heisenberg limited quantum metrology of a phase, without any prior, by employing only maximally entangled states. Starting from the estimator introduced by Higgins et al. in New J. Phys. 11, 073023 (2009), the main result discussed in the talk is an analytical upper bound on the associated Mean Squared Error which is monotonically decreasing as a function of the square of the number of quantum probes used in the process. The analyzed protocol is non-adaptive and requires in principle (for distinguishable probes) only separable measurements. From the practical point of view, at difference with the previous works, where it was required the states sizes to grow as the powers of two, we are often able to extract Heisenberg Scaling from an arbitrary sequence of entangled states sizes, possibly realizable in a laboratory. We also explore how the strategy changes in presence of probe loss or fluctuations of the phase. |
| 14:15 | Bound states in the continuum in arrays of quantum emitters<br>*Presenter: LONIGRO, Davide (University of Bari & INFN)*<br>Quantum emitters coupled to EM fields in waveguides provide a controllable and experimentally feasible testbed to observe interesting physical phenomena; in particular, the emergence of bound states in the continuum opens new possibilities to generate states with specific entanglement properties. We characterize analytically the bound states for any number of emitters, showing that the finite spacing between the emitters and the structure of the field dispersion relation become relevant and yield nonperturbative effects. |
| 14:30 | Quantum computing model of an artificial neuron with continuously valued input data<br>*Presenter: MANGINI, Stefano (University of Pavia)*<br>Artificial neural networks have been proposed as potential algorithms that could benefit from being implemented and run on quantum computers. In particular, they hold promise to greatly enhance Artificial Intelligence tasks, such as image elaboration or pattern recognition. The elementary building block of a neural network is an artificial neuron, i.e. a computational unit performing simple mathematical operations on a set of data in the form of an input vector. Starting from the design of a previously introduced quantum artificial neuron [1], which fully exploits the use of superposition states to encode binary valued input data, during the talk it will be shown how the implementation of the quantum neuron can be further generalized to accept continuous- instead of discrete-valued input vectors, without increasing the number of qubits [2]. This further step is crucial to allow for a direct application of gradient descent based learning procedures, which would not be compatible with binary-valued data encoding.<br><br>[1] Tacchino, F., Macchiavello, C., Gerace, D. et al. (2019). An artificial neuron implemented on an actual quantum processor. npj Quantum Inf 5, 26. https://doi.org/10.1038/s41534-019-0140-4<br>[2] Mangini, S., Tacchino, F., Gerace, D., Macchiavello, C. and Bajoni, D. (2020). Quantum computing model of an artificial neuron with continuously valued input data. Machine Learning: Science and Technology. https://doi.org/10.1088/2632-2153/abaf98 |
| 14:45 | Fighting qubit loss in topological QEC codes: theory and experiment<br>*Presenter: VODOLA, Davide (Bologna University)*<br>The loss of qubits poses one of the fundamental obstacles towards large-scale and fault-tolerant quantum information processors. In this work, we design and characterize a complete toolbox for a full cycle of qubit loss detection and correction on a minimal instance of a topological surface code. This includes a quantum non-demolition measurement of a qubit loss event that conditionally triggers a restoration procedure, mapping the logical qubit onto a new encoding on the remaining qubits. The demonstrated methods, implemented here in a trapped-ion quantum processor, are applicable to other quantum computing architectures and codes, including leading 2D and 3D topological quantum error correcting codes. These tools complement previously demonstrated techniques to correct computational errors, and in combination constitute essential building blocks for complete and scalable quantum error correction. |

**Break (15:00-15:15)**

**Contributed: Many-body (30 Sep 2020, 15:15-16:15)**

Chairperson: Francesco Ciccarello

| time | title |
| --- | --- |
| 15:15 | The Frustration of being Odd<br>*Presenter: MARIĆ, Vanja (SISSA Trieste, RBI Zagreb)*<br>A central tenant in the classification of phases is that boundary conditions cannot affect the bulk properties of a system. In our works, we show striking, yet puzzling, evidence of a clear violation of this assumption. We study some exactly solvable spin chains, mappable to free fermions, in a ring geometry with an odd number of sites. In such a setting, even at finite sizes, we are able to calculate directly the spontaneous magnetizations that are traditionally used as order parameters to characterize the system's phases. We find that boundary conditions can destroy local order, change it, and even induce a new quantum phase transition.<br><br>Main references: https://iopscience.iop.org/article/10.1088/1367-2630/aba064 https://arxiv.org/abs/2002.07197 |
| 15:22 | Bulk detection of time-dependent topological transitions in quenched chiral models<br>*Presenter: DI COLANDREA, Francesco (Università degli Studi di Napoli Federico II )*<br>The topology of one-dimensional chiral systems is captured by the winding number of the Hamiltonian eigenstates. We proved that this invariant can be read-out by measuring the Mean Chiral Displacement of a single-particle wavefunction that is connected to a fully localized one via a unitary and translation-invariant map. Remarkably, this implies that the Mean Chiral Displacement can detect the winding number even when the underlying Hamiltonian is quenched between different topological phases. We confirm experimentally these results in a photonic quantum walk, realized in the transverse-momentum space of structured light. |
| 15:30 | Witnesses of coherence and dimension from multiphoton indistinguishability tests<br>*Presenter: ESPOSITO, Chiara*<br>The quantum interference [1] is a useful tool for the characterization of the single photon sources, for quantum computing and for quantum communication. In particular, the indistinguishability and the superposition are the key elements of the quantum interference and for this reason, it is worth to develop better methods for their identification and quantification. We present an indistinguishability test for a multiphoton state based on two-photon Hong-Ou-Mandel tests. Our approach [2] consists of an interferometer that allows measure simultaneously the three photon overlaps on a four photon state produced by a spontaneous parametric down conversion(SPDC) source. As shown in Ref. [3], we quantify the indistinguishability from the obtained value measured overlaps. Starting from these measurements we infer precise bounds for the unmeasured overlaps. For this purpose, we assume two different models for the multiphoton state: generally mixed four-photon state [3], and the tensor product of pure single-photon state [4]. Each model provides different inequalities for the unmeasured overlaps. Furthermore, changing the number and the arrangement of HOM tests performed between pair of photon, i.e having access to different pairwise overlaps, other information can be retrieved on the system. From the same inequalities, we also can formulate a coherence witness and dimension witness based on this overlaps estimation, as shown in Ref. [4]. This basis-independent coherence witness attests that it is not possible to diagonalize the state on a given reference basis. We experimentally test this new coherence witness. In order to have a three photon state in input and measure the three pairwise possible overlaps, we rearrange our interferometer. To obtain the coherence witness violation, we tune the different input state by photon polarization. We also experimentally measure the Hilbert space dimension witness which attests if the space dimension of each photon state is up to two. For this purpose, we use the photon delay times as degree of freedom. In this way, we have three qudit states that violate the dimension witness. Our results confirm the validity of these novel coherence and dimension witnesses and they provide a complete characterization of the single photon sources. Moreover, the identification of an undesired degree of freedom makes the dimension witness very useful for quantum cryptography.<br><br>[1] Flamini, F., Spagnolo, N., & Sciarrino, F. “Photonic quantum information processing: a review.” Reports on Progress in Physics, 82(1), 016001 (2018).<br>[2] Giordani, T., Brod, D. J., Esposito, C., Viggianiello, N., Romano, M., Flamini, F., ... & Sciarrino, F. (2020). Experimental quantification of four-photon indistinguishability. New Journal of Physics.<br>[3] D. J. Brod, et al., “Witnessing genuine multiphoton indistinguishability,” Phys. Rev. Lett. 122, 063602 (2019).<br>[4] D. J. Brod and E. F. Galvão, “Quantum and classical bounds for unknown two-state overlaps” |

15:37 Vacancy-like dressed states in topological waveguide QED

*Presenter: LEONFORTE, Luca (University of Palermo)*

We identify a class of dressed atom-photon states forming at the same energy of the atom at any coupling strength. As a hallmark, their photonic component is an eigenstate of the bare photonic bath with a vacancy in place of the atom. The picture allows to formalize and re-interpret all quantum optics phenomena where atoms behave as perfect mirrors, connecting in particular dressed bound states (BS) in the continuum (or BIC) with geometrically-confined photonic modes in a waveguide. Most notably, when applied to photonic lattices, the framework allows to formulate for the first time a general criterion to predict atom-photon dressed BS in lattices with topological properties by putting them in one-to-one correspondence with photonic bound modes whose occurrence is ruled by the known Atland-Zirnbauer classification. The criterion is applied to predict new classes of dressed BS in the photonic Creutz-ladder and Haldane models. In the latter case, states with non-zero local photon flux occur where an atom is dressed by a photon orbiting around it, a phenomenon so far unexplored in quantum optics.

15:45 The complete spectrum of spin-1/2 XXZ chain at root of unity

*Presenter: MIAO, Yuan (Institute for Theoretical Physics, University of Amsterdam)*

We have studied the complete spectrum of spin-1/2 XXZ chain at root of unity, i.e. a paradigmatic model of quantum integrability. Making use of transfer matrix fusion relation, we constructed a family of 2-parameter transfer matrices, which help us obtain all the eigenstates in terms of Bethe roots. This elucidates a long-standing problem dated from the debate between McCoy and Baxter. We also exemplify the applications in the thermodynamic limit, which explains the rôle of quasi-local Z charge in the presence of quantum quenches and generalised hydrodynamics.

15:52 D-Wave as a generator of structural models in materials science

*Presenter: CARNEVALI, Virginia (Central Michigan University)*

A tool capable to efficiently generate realistic structural models of disordered systems has been a goal of material science for many years. We show the feasibility of quantum annealing in exploring the energy landscape of materials that deviate from the ideal crystalline phase, specifically vacancy defects in graphene and disordered silicon. By mapping the competing interactions onto quadratic unconstrained binary optimization problems (QUBO), our approach guarantees access to all the arrangements of the multiple defects on the graphene sheet respecting the relative formation energies. In the case of silicon a large portion of the structural models with an increasing disorder is encoded in the low energy spectrum of the QUBO formulation and detected in the annealing process. Our approach reproduces known results and provides a stepping-stone towards applications of quantum annealing to more complex problems of physical-chemical interest.

16:00 Modeling order-disorder phase transitions with a quantum annealer

*Presenter: SILOI, Ilaria (University of Southern California)*

Quantum annealers have grown in complexity to the point that devices with few thousand qubits are approaching capacities to tackle material science problems. Starting from a representation of crystal structures in terms of networks, we develop models of order-disorder phase transitions for two prototypical classes of materials (entropy stabilized alloys and perovskites) that are directly implementable on the D-Wave devices. Cost functions are built to encode the ordered phase, while disordered phases appear as excited states in the spectrum of the classical Ising Hamiltonian, which accounts for the competing interactions in the material. Taking advantage of the statistical nature of the quantum annealing, we explore the energy landscape and generate all the structural models for each step of the order-disorder phenomenon. Besides providing a correct description in terms of critical temperatures, our model allows us to access a wide range of structural models, overcoming some limitations of classical methods.

16:07 Mitigating quantum errors with Mitiq

*Presenter: SHAMMAH, Nathan (Unitary Fund)*

This talk introduces an open-source package for error-mitigation in quantum computation using zero-noise extrapolation. Error-mitigation techniques improve computational performance (with respect to noise) using minimal overhead in quantum resources by relying on a mixture of quantum sampling and classical post-processing techniques. Our error-mitigation package interfaces with multiple quantum computing software stacks, and we demonstrate improved performance on a variety of benchmarks performed on IBM and Rigetti quantum processors. We describe the library using code snippets to demonstrate usage and discuss features, support, and contribution guidelines.We also report on how cloud-based interactive workshops have helped develop the library with feedback from the research community.

**Break (16:15-16:30)**

## Invited: Condensed Matter (30 Sep 2020, 16:30-17:15)

Chairperson: Rosario Lo Franco

| time | title |
|---|---|
| 16:30 | Semiconductor qubits based on hole spins in CMOS devices and edge-states in Hall interferometers |

*Presenter: BELLENTANI , Laura (S3 CNR-Nano)*

Among the possible frameworks to encode the quantum bit, semiconductor-based implementations possibly present the highest potential in terms of scalability and compatibility with current nanoelectronics industry. In this talk, I will outline two different platforms for the realization of the qubit in semiconductor devices, and present the numerical approach we adopted for their characterization in full-scale simulations. The first approach, pursued within the recently started IQubits EU project [1], focuses on the use and engineering of fabricated CMOS devices to implement hole/electron spin qubits. The experimental characterization of a 22-nm FDSOI MOSFETs [2] has proved the formation of a double hole/electron quantum dot in the Si/SiGe channel, which potentially enables the monolithic integration of the control and readout circuitry on the same die [3]. The hole states are controlled by the top and back gates, while the spin is manipulated by electric-dipole spin resonance. Within a multiscale approach, we compute the single-hole states by diagonalizing the k·p Luttinger-Kohn Hamiltonian, starting from a realistic confining potential, simulated by means of the “Ginestra” software [4]. Prospects for scalability are included, starting from the simulation of double quantum dot systems in Si/SiGe MOSFETS, with a particular emphasis on the effects of Coulomb interactions and correlations. The second approach exploits topologically-protected edge states in the Integer Quantum Hall regime for a flying implementation of the quantum bit, with a coherence length up to 10 micrometers [5]. The qubit propagates at the edges of a confined 2DEG, while the inter-channel scattering rotates their state. Hall interferometers implement this manipulation protocol to realize single and two-qubit operation on the fly. We present our proposal for a Hall conditional phase shifter and show its feasibility for phase rotation up to π [6]. The exact two-electron wavefunction is evolved in the full-scale 2D potential of the device, where single-charges are injected as Gaussian wavepackets of edge states. Our numerical approach involves HPC techniques to include exactly the interplay between Coulomb repulsion and the device geometry, whose tuning is crucial for logic operations.

[1] www.iqubits.eu.
[2] S. Bonen et al., IEEE Electron Device Letters, 40 127-130 (2019).
[3] M. J. Gong et al., 2019 IEEE Radio Frequency Integrated Circuits Symposium (RFIC), Boston, MA, USA, pp. 111-114 (2019).
[4] www.mdlsoft.com.
[5] P. Roulleau et al., Phys. Rev. Lett. 100, 126802 (2008); E Bocquillon et al., Science 339 6123 (2013).
[6] L. Bellentani, G. Forghieri, P. Bordone and A. Bertoni, Phys. Rev. B 102, 035417 (2020).

| time | title |
|---|---|
| 16:45 | Vibrational modulation of electronic transitions in Copper Germanate: a theoretical model |

*Presenter: MARCANTONI, Stefano (University of Nottingham)*

The dynamics of complex materials can be conveniently investigated through pump-probe techniques. Here we present a simple quantum theoretical model that is used to interpret the results of a recently performed pump-probe experiment on Copper Germanate [1]. In this context, in order to study the electron-phonon coupling in the material, lattice vibrations are excited by an infrared pump pulse and d-d electronic transitions are probed with a visible pulse.

[1] A. Marciniak, et al. arXiv:2003.13447

17:00 Full control of nonlinear processes in Josephson parametric amplifiers for readout of superconducting qubits

*Presenter: MIANO, Alessandro (University of Naples Federico II)*

In the last decade, Superconducting Quantum Circuits (SQCs) based on Josepshon Junctions (JJs) showed that a working quantum processor can be successfully built and operated to perform Quantum Information Processing (QIP) on a system made of many superconducting qubits. The key ingredient to reach such an achievement are the endless possibilities allowed by SQCs in order to efficiently control and readout superconducting qubits, and the research on these interface devices is at the edge of technological advances in QIP. Efficient readout of superconducting qubits requires coherent amplification of single microwave photon signals while preserving a high Signal to Noise Ratio (SNR) in order to reach high single-shot readout fidelity. This task can be achieved by driving parametric processes in superconducting nonlinear oscillators, allowing coherent energy transfer between a strong pump and a single microwave photon signal that carries the result of a Quantum Non-Demolition measurement on a qubit. Thanks to these techniques, it is possible to build Quantum Limited Amplifiers (QLA) that can generate well detectable signals with SNR being degraded only by the least amount imposed by quantum mechanical principles. A QLA can be built around Josephson microwave circuits that synthesize nonlinear Hamiltonians with the required characteristics, and established devices are nowadays used in every superconducting quantum computing experiment. However, the trigonometric nature of the Josephson nonlinearities makes their independent control a challenging task. We show how is possible to improve the synthesis capabilities of Josephson Hamiltonians with a “Gradiometric SNAIL Parametric Amplifier” (G-SPA), a novel Josephson parametric amplifier that allows complete tuning of its nonlinearities via in-situ magnetic fluxes. Our approach expands the tunability range of the parametric processes, allowing independent choice of their participation in the treatment of single photon signals and opening to many new applications for these devices.

**Break (17:15-17:30)**

## Career Panel: Publishing (30 Sep 2020, 17:30-18:30)

Moderator: Matteo G. A. Paris

| time | title |
|---|---|
| 17:30 | Career panel: Publishing<br>Panelists:<br><br>Katiuscia Cassemiro (Physical Review X Quantum - American Physical Society)<br><br>Jean-Sébastien Caux (University of Amsterdam and SciPost)<br><br>Gaia Donati (Zurich Instruments)<br><br>Alison Taylor (Optical Society of America) |

**Break (18:30-19:30)**

## Beers and Posters: Day 2 (30 Sep 2020, 19:30-21:00)

| time | title |
|---|---|
| 19:30 P25 | Noisy propagation of Gaussian states in optical media with finite bandwidth<br>*Presenter: PARIS, Matteo (University of Milan)*<br>We address the propagation of Gaussian states of light in optical media with a finite bandwidth. Upon assuming weak coupling and low temperature we show that attenuation (damping) is strongly suppressed and that the overall diffusion process may be described by a Gaussian noisy channel with variance dependening only on bandwidth. |
| 19:30 P26 | Meter sensitivity in quantum measurements<br>*Presenter: MATSUSHITA, Tomonori (Hiroshima University)*<br>Quantum systems can only be measured by interactions with an external meter. This interaction is described by a unitary transformation that involves quantum superpositions in both the system and the meter. In this presentation, we analyze the sensitivity of the quantum coherent meter response using the Fisher information. It is shown that the sensitivity of the meter is limited by quantum fluctuations that have a direct effect on the dynamics of the system during the interaction. |
| 19:30 P27 | Suppressing decoherence in quantum computers with unitary operations<br>*Presenter: MASTIUKOVA, Alena (Moscow Institute of Physics and Technology, National Research University)*<br>Decoherence is a fundamental obstacle to the implementation of large-scale and low-noise quantum computing devices. In the present work, we investigate the role of the fidelity of finite-dimensional quantum systems in the context of their robustness to decoherence. We suggest an approach for suppressing errors by employing pre-processing and post-processing unitary operations, which precede and follow the action of a decoherence channel. The suggested approach relies on specifically designed unitary operators for a particular state without the need in ancillary qubits or post-selection procedures. We consider the realization of our approach for the basic decoherence models, which include single-qubit depolarizing, dephasing, and amplitude damping channels. We demonstrate that for the case of depolarization channels there is a general relation between linear entropies of quantum states and fidelities of the quantum state after the action of the depolarizing channel on a particular subsystem of quantum states. We prove the general relation between linear entropies of quantum states for depolarization channels and illustrate it for qubit systems and we consider a generalization of the suggested approach for qudit ensembles. |
| 19:30 P28 | Spintronic characteristics of self-assembled acetylcholine molecular complexes<br>*Presenter: MAJAUSKAITE, Kristina (Institute of Biochemistry, Life Sciences Center, Vilnius University)*<br>We are interested in quantum features of acetylcholine (ACh) and its complexes, because ACh is a prominent neurotransmitter of the peripheral and the central nervous system. The synaptic release of ACh, called cholinergic transmission, is widespread, occurring centrally, deep in the cortex, and in the distal periphery, where motoneurons contact muscles. The density functional theory (DFT) was used to investigate ACh molecule and its complexes in various charged and spin multiplicity states. We may expect that quantum effects can be observed in proposed complex systems of acetylcholine molecules, which are stochastically self-assembling in neural networks or brain, and once again hydrolyzing. During the short period of self-assembly ordered arrays of acetylcholine molecules we may expect the quantum information processing due to interaction of ordered spin dipoles. |
| 19:30 P29 | Two-fermions molecules in a harmonic trap with short-range interaction<br>*Presenter: JIMÉNEZ, Martín (Universidad Nacional de Córdoba)*<br>Low-particle systems constitute a direct link between the physics of one or two bodies and the physics of many bodies. This connection has important consequences related to the collective properties that originate in the interactions between particles and in the statistic that governs them. We study a system consisting of independent molecules formed by two distinguishable fermions that interact via a contact potential in an elongated harmonic trap (this was already experimentally achieved), so the system can effectively be considered as 1D. We focus on the entanglement between the constituents of the molecule. By using an ansatz of composite bosons for the fundamental state, we analyze properties such as the condensate fraction, the occupancy numbers of the Schmidt modes, and the density profile of a particle both, when adding molecules to the system and when the interaction parameter between the constituent fermions is modified. In the strongly attractive regime, the pair is maximally entangled and the molecules behave like ideal bosons (BECs). On the other hand, in the strongly repulsive regime, the system exhibits a finite but not maximum amount of entanglement. The fermionization phenomenon is also studied in this regime. Our analysis paves the way to the exploration of 1D Fermi gases with an arbitrary number of pairs across the full interaction range. |

19:30 **P30** Qutrit based semi-quantum key distribution protocol

*Presenter: HAJJI, Hasnaa (Mohammed V University, Faculty of Sciences)*

This work provides the unconditional security of a semi quantum key distribution (SQKD) protocol based on 3-dimensional quantum states. By deriving a lower bound for the key rate, in the asymptotic scenario, as a function of the quantum channel's noise, we nd that this protocol has improved secret key rate with much more tolerance for noise compared to the previous 2-dimensional SQKD protocol. Our results highlight that, similar to the fully quantum key distribution protocol, increasing the dimension of the system can increase the noise tolerance in the semi-quantum key distribution, as well.

19:30 **P31** Entaglement-Based Quantum Mean Estimator Circuit

*Presenter: GETACHEW, Amanuel Tamirat (Wolkite University)*

This paper proposes a quantum circuit for computing the mean value from a given set of quantum states. The circuit consults a Quantum Random Access Memory to get the values of the set, and by using superposition, interference and entanglement phenomena, it can estimate the mean value in $\mathcal{O}(\frac{1}{\epsilon}\log{Nd})$ complexity. The proposed quantum mean-estimator circuit has been simulated on the IBM Q Experience and the results suggest that the proposed quantum circuit can have the potential to enhance many mean-based machine learning algorithms.

19:30 **P32** A quantum model for rf-SQUIDs based metamaterials enabling 3WM and 4WM Travelling Wave Parametric Amplification

*Presenter: FASOLO, Luca (Politecnico di Torino and Istituto Nazionale di Ricerca Metrologica)*

In superconducting quantum computing a qubit state can be inferred through the measurement of low-power microwave fields. In this context, the large bandwidth and ultralow-noise amplification given by a Travelling Wave Josephson Parametric Amplifier (TWJPA) plays an essential role. In our work we derive a quantum model for an rf-SQUID (rf-Superconducting QUantum Interference Device) based TWJPA, enabling the amplification of the input signal through a three-wave or a four-wave mixing process. These two different working regimes can be properly selected by changing the external bias conditions, represented by a DC current or a magnetic flux. Within the model, we derive an analytical expression for the gain and the squeezing of a given input signal at the single-photon level. Furthermore, we investigate the time evolution inside the device of the probability distribution of the photonic population in the particular cases of two-mode Fock and coherent input states.

19:30 **P33** Aperiodic space-inhomogeneous quantum walks: Localization properties, energy spectra, and enhancement of entanglement

*Presenter: DA SILVA DIAS, Wandearley (Universidade Federal de Alagoas)*

We study the localization properties, energy spectra, and coin-position entanglement of the aperiodic discrete-time quantum walks. The aperiodicity is described by spatially dependent quantum coins distributed on the lattice, whose distribution is neither periodic (Bloch-like) nor random (Anderson-like). Within transport properties we identified delocalized and localized quantum walks mediated by a proper adjusting of aperiodic parameter. Both scenarios are studied by exploring typical quantities (inverse participation ratio, survival probability, and wave packet width), as well as the energy spectra of an associated effective Hamiltonian. By using the energy spectra analysis, we show that the early stage the inhomogeneity leads to a vanishing gap between two main bands, which justifies the predominantly delocalized character observed for $\nu < 0.5$. With increase of $\nu$ arise gaps and flat bands on the energy spectra, which corroborates the suppression of transport detected for $\nu > 0.5$. For $\nu$ high enough, we observe an energy spectra, which resembles that described by the one-dimensional Anderson model. Within coin-position entanglement, we show many settings in which an enhancement in the ability to entangle is observed. This behavior brings new information about the role played by aperiodicity on the coin-position entanglement for static inhomogeneous systems, reported before as almost always reducing the entanglement when comparing with the homogeneous case. We extend the analysis in order to show that systems with static inhomogeneity are able to exhibit asymptotic limit of entanglement.

19:30 P34

### Violation of TUR in a periodically driven quantum work-to-work converter

*Presenter: CANGEMI, Loris Maria (University of Naples Federico II)*

Microscopic systems driven out of equilibrium and put in contact with thermal reservoirs act as prototypes of stochastic cyclic heat engines [1,2]. In these engines, thermal fluctuations of heat, work and entropy production cannot be neglected, and the concepts of classical thermodynamics need to be generalized to microscopic nonequilibrium regime [3]. Employing the theoretical framework of Stochastic Thermodynamics (ST), in the case of autonomous steady-state thermal machines, Thermodynamics Uncertainty Relations (TUR) have been proved [4], setting a trade-off to entropy production, output power and output power fluctuations. It follows that microscopic heat engines operating at near-to-zero entropy production cannot be achieved without a divergence in the relative output power fluctuations. On the other hand, in the last decades several models of quantum heat engines and refrigerators have been devised, where the working media obey the laws of quantum mechanics. Single driven qubits [5], pairs of qubits subject to unitary gates [6], quantum dots, as well as many-body systems near criticality [7] have been considered. Many interesting results have been obtained concerning the engine efficiency at maximum power, as well as the possibility to attain Carnot efficiency at finite power. Despite all the efforts, it is rather unclear whether or not quantum heat engines could achieve enhanced performance in heat-to-work conversion with respect to their classical counterparts. In addition, the experimental realizations of these engines are still in their infancy. In this work, we study a model of simple yet nontrivial quantum system, i.e. a qubit, which is driven out of equilibrium by means of a couple of external, time-periodic fields and is permanently put in contact with a thermal reservoir, inducing dissipation and decoherence [8]. Under suitable conditions, the system acts as an isothermal steady-state work-to-work converter, i.e. it converts a given amount of work provided in the input channel to the output channel with fixed efficiency [9]. The converter operates in the absence of Time-Reversal (TR) symmetry. We combine analytical and numerical approaches to study the converter performance as function of the model parameters, without restricting our analysis to weak system-bath coupling regime. We test the validity of the recently derived dynamic TUR [10], showing that several regions of the model parameter space exist where the quantum converter does not obey TUR. We link the occurrence of the violation to the degree of quantum coherence in the converter dynamics.

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[2] V. Holubec, Journal of Statistical Mechanics: Theory and Experiment 5, P05022 (2014).
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[4] P. Pietzonka and U. Seifert, Phys. Rev. Lett. 120, 190602 (2018).
[5] Gelbwaser-Klimovsky, D. and Alicki, R. and Kurizki, G., Phys. Rev. E 87, 012140 (2013).
[6] M. Campisi, J. Pekola and R. Fazio, New Journal of Physics, 17, 3, 035012 (2015).
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[8] L. M. Cangemi, V. Cataudella, G. Benenti, M. Sassetti and G. De Filippis, arXiv:2004.02987, (Submitted to Physical Review B) (2020).
[9] M. Carrega, M. Sassetti and U. Weiss, Phys. Rev. A 99, 062111 (2019).
[10] T. Koyuk and U. Seifert, Phys. Rev. Lett. 122, 230601 (2019).

19:30 P35

### Self-trapped quantum walks

*Presenter: BUARQUE, Anderson (Universidade Federal de Alagoas)*

We study the existence and charaterization of self-trapping phenomena in discrete-time quantum walks. By considering a Kerr-like nonlinearity, we associate an acquisition of the intensity-dependent phase to the walker while it propagates on the lattice. Adjusting the nonlinear parameter (χ) and the quantum gates (θ), we will show the existence of different quantum walking regimes, including those with travelling soliton-like structures or localized by self-trapping.

19:30 P36

### Generalized coherent vector: definition and applications

*Presenter: BOSYK, Gustavo Martin (Instituto de Física La Plata, CONICET-UNLP & Università degli Studi di Cagliari)*

We advance on the characterization of quantum coherence resource theory, by introducing the notion of coherence vector of a general quantum state. We show that the coherence vector completely characterizes the notions of being incoherent, as well as being maximally coherent. Moreover, using this notion and the majorization relation, we obtain a necessary condition for the conversion of general quantum states by means of incoherent operations. Finally, we introduce a family of coherence monotones by considering concave and symmetric functions applied to the coherence vector of a general quantum state. We compare this proposal with the convex roof measure of coherence and others quantifiers given in the literature.

19:30 **P37** Quantum discord based on linear entropy and thermal entanglement of qutrit-qubit spin chain under influence of the external magnetic field

*Presenter: BENABDALLAH, Fadwa (LPHE-Modeling and Simulation, Faculty of Sciences, Mohammed V University in Rabat)*

Quantum entanglement plays important roles in many areas of quantum information processing (QIP). Nevertheless, quantum entanglement is not the only form of quantum correlation that is useful for QIP. In fact, some separable states may also speed up certain quantum tasks, relative to their classical counterparts. Example of such quantum correlations, is a quantity, called quantum discord (QD), which can effectively capture all quantum correlations present in various kinds of quantum systems. The quantum discord involves a minimization procedure that is difficult to solve in general. To overcome the difficulty encountered with the computability of quantum discord based on von Neumann entropy, we propose a reliable analytical method to evaluate the quantum discord based on linear entropy for an arbitrary qudit-qubit quantum state. The quantum discord based on linear entropy is employed to derive the amount of quantum correlations in a qutrit-qubit mixed spin system in the thermal equilibrium at temperature T. We investigated also the situation when the system is embedded in an external magnetic field B. The obtained amount of quantum discord is then compared with the measurement-induced disturbance (MID) and logarithmic negativity (LN). The results for B = 0 are shown in (Fig.1). The analysis shows that the quantum discord based on the linear entropy behaves like measurement induced disturbance. This indicates that this variant of quantum discord is a useful tool to deal with quantum correlations between multi-component systems of higher dimensional Hilbert spaces. Besides, both QD and MID are robust than thermal entanglement against the temperature T. Further, QD and MID are able to detect the critical points of transition QPT, while the logarithmic negativity cannot provide such indication.

19:30 **P38** Compressed Sensing Quantum State Tomography: An Alternate Approach

*Presenter: BADVELI, Revanth (Birla Institute of Technology and Science, Pilani)*

The matrix generalizations of Compressed Sensing (CS) were adapted to Quantum State Tomography (QST) previously by Gross et al. [Phys. Rev. Lett. 105, 150401 (2010)], where they consider the tomography of n spin-1/2 systems. For the density matrix of dimension d = 2^n and rank r with r << 2^n, it was shown that randomly chosen Pauli measurements of the order O[dr log(d)^2] are enough to fully reconstruct the density matrix by running a specific convex optimization algorithm. The result utilized the low operator-norm of the Pauli operator basis, which makes it “incoherent" to low-rank matrices. For quantum systems of dimension d not a power of two, Pauli measurements are not available, and one may consider using SU(d) measurements. Here, we point out that the SU(d) operators, owing to their high operator norm, do not provide a significant savings in the number of measurement settings required for successful recovery of all rank-r states. In this work [Phys. Rev. A 101, 062328], we propose an alternative strategy, in which the quantum information is swapped into the subspace of a power-two system using only poly[log(d)^2] gates at most, with QST being implemented subsequently by performing O[dr log(d)^2] Pauli measurements. We show that, despite the increased dimensionality, this method is more efficient than the one using SU(d) measurements.

19:30 **P39** Quantum Neural Networks - Towards an era of Quantum-Assisted Machine Learning

*Presenter: AZAD, Utkarsh (International Institute of Information Technology, Hyderabad)*

Fault-tolerant universal quantum computers still appear to be more than a decade away. However, consistent growth in the field of quantum technologies over the years has lead to the development of Noisy Intermediate-Scale Quantum (NISQ) devices. The computational capabilities of these devices are considerably restricted due to limited connectivity, short coherence time, poor qubit quality and minimal error-correction. A particular class of useful algorithms that can be executed on these devices are variational algorithms which use the following hybrid approach: Prepare a highly entangled quantum state using a limited depth quantum processor, then apply a classical optimization routine on the gate parameters to converge to that quantum state for which the objective function is minimized. Availability of massive amounts of data in the natural sciences has enabled the use of machine learning (ML) and artificial intelligence (AI) for tasks ranging from molecular discovery to prediction of new genes. Despite the excitement and promising results, the requirement of extensive computational resources to train ML models largely restricts their current applicability. Various proposals have been made to overcome this bottleneck, and one of them is to use quantum computers to achieve significant speedups. In the same spirit, we showcase a quantum-assisted approach in which a QPC is used as a machine learning model and optimized using a scheme similar to back-propagation in feedforward neural networks. In general, such a circuit (model) can then be trained for a given labelled dataset {x; f(x)} on current generation NISQ devices to perform classification and regression tasks by learning a function f(x). In this work, we investigate a hybrid quantum-classical (HQC) approach to envisage a quantum neural network using quantum parameterized circuits (QPCs). To simulate these quantum circuits, we make use of three different libraries based on the task at hand: Pennylane by Xanadu, pyQuil by Rigetti and Qiskit by IBM. Our analysis shows that given enough labelled training data points, a QPC with sufficient qubits and depth can be trained using classical optimization routines to perform both regression and classification tasks.

19:30 **P40** Towards fault-tolerant quantum computation based on near-field microwaves with trapped ions

*Presenter: ZARANTONELLO, Giorgio (Leibniz Universität Hannover)*

The fault-tolerant regime allows a quantum computer to perform a quantum algorithm with arbitrary precision. To do so it is necessary to perform all single-qubit and two-qubit entangling gates with a low enough infidelity. In the context of trapped-ion quantum computing, operations based on microwaves are an alternative to the more diffused laser driven operations. Due to their lower frequencies, microwave gates are not limited by the errors induced by photon scattering typical of optical gates. For surface-electrode ion traps it is possible to embed the required microwave conductors directly into the trap structure to generate the oscillating magnetic field for single-qubit and multi-qubit gates [1]. I will report the results from our experiment where we have achieved a two-qubit entangling gate infidelity in the 10-3 range [2]. I will discuss how amplitude modulation of the microwave signal has been used to increase the robustness of such gates against one of the biggest sources of infidelities, motional mode frequency fluctuations. To realize a scalable ion trap processor based on microwaves, it is possible to use a novel fabrication method developed in our group [3-4]. The use of high-fidelity operations, combined with a scalable trap structure, opens the possibility to perform large scale quantum computation in the near future.

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[2] G. Zarantonello et al., Phys. Rev. Lett. 123 260503 (2019)
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19:30 **P41** Quantum fluctuations hinder finite-time information erasure near the Landauer limit

*Presenter: GUARNIERI, Giacomo (Trinity College Dublin)*

Information is physical but information is also processed in finite time. Where computing protocols are concerned, finite-time processing in the quantum regime can dynamically generate coherence. Here we show that this can have significant thermodynamic implications. We demonstrate that quantum coherence generated in the energy eigenbasis of a system undergoing a finite-time information erasure protocol yields rare events with extreme dissipation. These fluctuations are of purely quantum origin. By studying the full statistics of the dissipated heat in the slow driving limit, we prove that coherence provides a non-negative contribution to all statistical cumulants. Using the simple and paradigmatic example of single bit erasure, we show that these extreme dissipation events yield distinct, experimentally distinguishable signatures.

19:30 **P42** Relative decoherence in quantum reference frames

*Presenter: TUZIEMSKI, Jan (Stockholm University)*

Reference frames are of special importance in physics. They are usually considered to be idealized entities. However, in most situations, e.g. in laboratories, physical processes are described within reference frames constituted by physical systems. As new technological developments make it possible to demonstrate quantum properties of complex objects an interesting conceptual problem arises: Could one use states of quantum systems to define reference frames? Recently such a framework has been introduced in [F. Giacomini, E. Castro-Ruiz, and Č. Brukner, Nat Commun 10, 494 (2019)]. One of its consequences is the fact that quantum correlations depend on a physical state of an observers reference frame. The aim of this work is to examine the dynamical aspect of this phenomena and show that the same is true for correlations established during an evolution of a composite systems. Therefore, decoherence process is also relative: For some observers the reduced evolution of subsystems is unitary, whereas for others not. I also discuss implications of this results for modern developments of decoherence theory: Quantum Darwinism and Spectrum Broadcast Structures.

19:30 **P43** Quantifying the efficiency of state preparation via quantum variational eigensolvers

*Presenter: MATOS, Gabriel (University of Leeds)*

Recently, there has been much interest in the efficient preparation of complex quantum states using low-depth quantum circuits, such as Quantum Approximate Optimization Algorithm (QAOA). While it has been numerically shown that such algorithms prepare certain correlated states of quantum spins with surprising accuracy, a systematic way of quantifying the efficiency of QAOA in general classes of models has been lacking. Here, we propose that the success of QAOA in preparing ordered states is related to the interaction distance of the target state, which measures how close that state is to the manifold of all Gaussian states in an arbitrary basis of single-particle modes. We numerically verify this for the ground state of the quantum Ising model with arbitrary transverse and longitudinal field strengths, a canonical example of a non-integrable model. Our results suggest that the structure of the entanglement spectrum, as witnessed by the interaction distance, correlates with the success of QAOA state preparation. We conclude that QAOA typically finds a solution that perturbs around the closest free-fermion state.

19:30 P44

### Adaptive phase estimation through a genetic algorithm

*Presenter: RAMBHATLA, Kartikeya (Shiv Nadar University)*

One of the fundamental motivations for science and technology is measurement of parameters with extreme precision. Quantum metrology is a significant application of quantum information theory for emerging quantum technologies, which exploits the theories of quantum mechanics, like entanglement, to surpass the limits on measurement and estimation of parameters realized using only classical techniques [1]. Phase estimation is a framework of quantum metrology where the challenge is estimation of unknown phase shifts by developing optimal protocols that estimate the phase to maximum possible precision by exploiting minimum number of resources [2,3]. We have designed a robust machine learning algorithm for the process of adaptive feedback based phase estimation using single photons in a Mach-Zehnder interferometer, which is able to deliver high performance using only a few resources [4]. The designed algorithm is a Genetic Algorithm, which is a search based evolutionary algorithm used for an offline optimization of control feedback policies that are used during the phase estimation process. The results of estimation show that the value of the unknown phase can be estimated using a limited number of photons, with an accuracy close to the theoretical limits. We also explored the performance of our algorithm in the presence of usual sources of errors, in order to concoct noise-robust policies that are tailored for both noisy and noiseless cases. Our results illustrate the potential of extending such methodologies to other applications in quantum metrology and for solving more general problems related to quantum information, where an adaptive approach could be used with optimal feedback control.

[1] V. Giovannetti, S. Lloyd, and L. Maccone, “Quantum-enhanced measurements: beating the standard quantum limit,” Science, vol. 306, no. 5700, pp. 1330–1336, 2004.
[2] A. Hentschel and B. C. Sanders, “Efficient algorithm for optimizing adaptive quantum metrology processes,” Physical Review Letters, vol. 107, no. 23, p. 233601, 2011.
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19:30 P45

### Quantum Advantage in Shared Randomness Processing

*Presenter: BANIK, Manik (Indian Institute of Science Education and Research, Thiruvananthapuram, India )*

Randomness appears both in classical stochastic physics and in quantum mechanics. In this work, we address a computational scenario of shared randomness processing where quantum sources manifest clear-cut precedence over the classical counterpart. For proper apprehension of the quantum advantage we formulate a resource theoretic framework for shared randomness processing. The advantage is operationally viable as it is manifested in the optimal classical vs quantum payoffs of a game involving two players. In distributing shared randomness between distant parties, we also exhibit advantage of quantum channel over its classical counterpart though the classical capacity of the former is fundamentally constrained by Holevo bound. Surprisingly, the advantage persists even when the channel has zero quantum capacity and classical capacity much less than unity. The noisy channel examples also facilitate noise-robust empirical setups to verify the obtained quantum advantage.

19:30 P46

### An uncertainty view on complementarity and a complementarity view on uncertainty

*Presenter: BASSO, Marcos (Federal University of Santa Maria)*

Quantum phenomena are manifestly unpredictable. While classical uncertainty arises from ignorance, quantum uncertainty is intrinsic. Even for pure quantum states that represents the maximal knowledge that one could have about quantum states, we can only make probabilistic predictions. In addition, when the state is mixed, the variance is a hybrid of quantum and classical uncertainties. Another intriguing aspect of quantum mechanics is the wave-particle duality. This characteristic is generally captured, in a qualitative way, by Bohr’s complementarity principle, and more recently, quantified by the well known complementarity relations. Complementarity relations are saturated only for pure, single-quanton, quantum states. For mixed states, the wave-particle quantifiers never saturate the complementarity relation and can even reach zero for a maximally mixed state. So, to fully characterize a quanton it is not sufficient to consider its wave-particle aspect; one has also to regard its correlations with other systems. In [1], we discussed the relation between quantum correlations and local classical uncertainty measures, as well as the relation between quantum coherence and quantum uncertainty quantifiers. Beyond, we obtained a complete complementarity relation for quantum uncertainty, classical uncertainty, and predictability. The total quantum uncertainty of a d-paths interferometer is shown to be equivalent to the Wigner-Yanase coherence and the corresponding classical uncertainty is shown to be a quantum correlation quantifier.

[1] M. L. W. Basso, J. Maziero, An uncertainty view on complementarity and a complementarity view on uncertainty,arXiv:2007.05053 [quant-ph] (2020).

19:30 P47

**Testing quantum speedups in exciton transport through a photosynthetic complex using quantum stochastic walks**

*Presenter: BENJAMIN, Colin (National Institute of Science education and research)*

Photosynthesis is a highly efficient process, nearly 100 percent of the red photons falling on the surface of leaves reach the reaction center and get transformed into energy. Quantum coherence has been speculated to play a significant role in this very efficient transport process which involves photons transforming to excitons and then traveling to the reaction center. Studies on photosynthetic complexes focus mainly on the Fenna-Matthews-Olson complex obtained from green-sulfur bacteria. However, there has been a debate regarding whether quantum coherence results in any speedup of the exciton transport process. To address this we model exciton transport in FMO using a quantum stochastic walk(QSW) with either pure dephasing or with both dephasing and incoherence. We find that the QSW model with pure dephasing leads to a substantial quantum speedup as compared to a QSW model which includes both dephasing and incoherence.

# Thursday 01 October 2020

**Social Event: Q&A with Scott Aaronson (1 Oct 2020, 18:00-20:00)**

Moderator: Fabio Benatti

# Friday 02 October 2020

## **Invited: Fundamental Aspects** (2 Oct 2020, 14:00-15:00)

Chairperson: Mauro Paternostro

| time | title |
|---|---|
| 14:00 | Entanglement of formation of mixed many-body quantum states using tensor networks<br>*Presenter: ARCECI, Luca (Università di Padova)*<br>In this talk, we will present an algorithm to compute the entanglement of formation for mixed many-body quantum states by using tensor networks. Indeed, we will introduce a new tensor network ansatz --- the Tree Tensor Operator --- which leads to a very convenient description of density matrices. Our results will focus on thermal states of the quantum Ising chain in transverse field, for which we could consider up to 22 spins. |
| 14:15 | There is only one time<br>*Presenter: COPPO, Alessandro (Università degli studi di Firenze)*<br>We draw a picture of physical systems that allows us to recognize what is this thing called "time" by requiring consistency not only with our notion of time but also with the way time enters the fundamental laws of Physics, independently of one using a classical or a quantum description. Elements of the picture are two non-interacting and yet entangled quantum systems, one of which acting as a clock, and the other one doomed to evolve. The setting is based on the so called "Page and Wootters (PaW) mechanism", and updates, with tools from Lie-Group and large-N quantum approaches. The overall scheme is quantum, but the theoretical framework allows us to take the classical limit, either of the clock only, or of the clock and the evolving system altogether; we thus derive the Schrödinger equation in the first case, and the Hamilton equations of motion in the second one. Suggestions about possible links with general relativity and gravity are also put forward. |
| 14:30 | Nonclassical steering and the Gaussian steering triangoloids<br>*Presenter: FRIGERIO, Massimo (Università degli Studi di Milano)*<br>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 (TMSTs), 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. We show that EPR-steering and weak/strong nonclassical steering merge precisely for TMSTs, and we discuss applications of this result to one-sided device-independent quantum key distribution and noisy propagation of twin-beam states. |
| 14:45 | Witnesses of non-classicality beyond quantum theory<br>*Presenter: MARLETTO, Chiara (University of Oxford)*<br>I discuss general argument to show that if a physical system can mediate locally the generation of entanglement between two quantum systems, then it itself must be non-classical. Remarkably, the argument does not assume any classical or quantum formalism to describe the mediating physical system: the result follows from general information-theoretic principles, drawn from the recently proposed constructor theory of information. This argument provides the indispensable theoretical basis for recently proposed tests of non-classicality in gravity, based on witnessing gravitationally-induced entanglement in quantum probes. |

**Break (15:00-15:15)**

## Contributed: Quantum Information (2 Oct 2020, 15:15-16:15)

Chairperson: Paolo Facchi

| time | title |
| --- | --- |
| 15:15 | Characterising quantum correlations of fixed dimension<br>*Presenter: SPARACIARI, Carlo (UCL)*<br>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 for general quantum correlations, we identify additional semidefinite constraints for any fixed dimension, leading to analytical bounds on the convergence speed of the resulting hierarchy. Additionally, we provide an algorithm, built upon our hierarchy, able to compute additive approximations on the value of two-player free games with an assisting quantum system of fixed dimension, and a given number of questions $\|Q\|$ and answers $\|A\|$. The computational time of our algorithm scales polynomially in $\|Q\|$ and quasi-polynomially in $\|A\|$, thereby improving on previously known approximation algorithms for which worst-case run-time guarantees were at best exponential in $\|Q\|\|A\|$. To derive our analytical bounds on the convergence of the hierarchy, we make a connection to the quantum separability problem and employ, as our main technical tool, an improved multipartite quantum de Finetti theorem with linear constraints. |
| 15:22 | Robust entanglement preparation against noise by controlling spatial indistinguishability<br>*Presenter: NOSRATI, Farzam (University of Palermo)*<br>Initialization of composite quantum systems into highly entangled states is usually a must to enable their use for quantum technologies. However, unavoidable noise in the preparation stage makes the system state mixed, hindering this goal. Here, we address this problem in the context of identical particle systems within the operational framework of spatially localized operations and classical communication (sLOCC). We define the entanglement of formation for an arbitrary state of two identical qubits. We then introduce an entropic measure of spatial indistinguishability as an information resource. Thanks to these tools we find that spatial indistinguishability, even partial, can be a property shielding non-local entanglement from preparation noise, independently of the exact shape of spatial wave functions. These results prove quantum indistinguishability is an inherent control for noise-free entanglement generation. |
| 15:30 | Entanglement of identical particles<br>*Presenter: JOHANN, Till (Ruprecht-Karls-Universität Heidelberg)*<br>Entanglement is a well defined and useful notion for distinguishable particles. It provides a framework of locality and can be used as a resource in quantum information and communication protocols. However, for identical particles, no universal accepted definition exists. The symmetrization principle makes identical particle states look entangled when written in first quantization notation. In particular, the state of two hydrogen atoms, one on the moon and one on the earth, which have never met each other cannot be written as a tensor product. However, because of the symmetrization, one also has to restrict the allowed operators on the Hilbert space. This means that one cannot easily infer nontrivial correlations in the systems by comparing the states of identical particles with their distinguishable counterparts. In my seminar, I want to address the question of entanglement for identical particles, with the particular example of the aforementioned hydrogen atoms. We will use recently developed guiding principles to motivate a useful notion of entanglement and show how to apply it on this given problem. |
| 15:37 | Noise-Resilient Variational Hybrid Quantum-Classical Optimization<br>*Presenter: GENTINI, Laura (University of Florence)*<br>Variational hybrid quantum-classical optimization represents one of the most promising avenue to show the advantage of nowadays noisy intermediate-scale quantum computers in solving hard problems, such as finding the minimum-energy state of a Hamiltonian or solving some machine-learning tasks. In these devices noise is unavoidable and impossible to error-correct, yet its role in the optimization process is not much understood, especially from the theoretical viewpoint. Here we consider a minimization problem with respect to a variational state, iteratively obtained via a parametric quantum circuit, taking into account both the role of noise and the stochastic nature of quantum measurement outcomes. We show that the accuracy of the result obtained for a fixed number of iterations is bounded by a quantity related to the Quantum Fisher Information of the variational state. Using this bound, we study the convergence property of the quantum approximate optimization algorithm under realistic noise models, showing the robustness of the algorithm against different noise strengths. |

**15:45** Manipulation and reconstruction of high-dimensional states

*Presenter: SUPRANO, Alessia (Università di Roma "Sapienza")*

The capability to control and manipulate high dimensional quantum states has become relevant in several fields ranging from the probing of fundamentals of quantum mechanics to the development of safer encryption algorithms. Various engineering techniques of high dimensional quantum states have been proposed, but they strongly depend on the experimental platform and do not provide a general scheme. Here, we experimentally demonstrate an engineering protocol based on the Quantum Walk (QW) dynamic encoding the walker state in the orbital angular momentum (OAM) degree of freedom and the coin state in the spin angular momentum (SAM). The QW dynamic allows the implementation of a platform-independent scheme to engineer qudit states encoded in the walker system. Each step of the 5-steps QW is composed of a set of wave-plates that manipulate the coin state and a peculiar device, the q-plate, that can conditionally change the OAM according to the polarization. Consequently, the walker dynamics are controlled by a suitable choice of step-dependent coin operators. Moreover, decode the information stored in the OAM states is challenging experimentally and theoretically. Indeed, the platforms proposed envisage additional instruments, such as interferometry and spatial filtering, that introduce damaging noise and loss. In this regard, we characterized structured beams where the helicoidal wavefront is coupled with a not uniform distribution of the polarization on the transverse plane (Vector Vortex Beam), by using both supervised and unsupervised machine learning techniques. In particular, we obtained optimal results characterizing 15 experimental classes using both Convolutional Neural Network or Support Vector Machine supported by Principal Component Analysis (PCA). The regression task is addressed too, leveraging PCA to reconstruct a specific class of Vector Vortex Beams.

**15:52** The quantum Wasserstein distance of order 1

*Presenter: DE PALMA, Giacomo (MIT)*

We propose a generalization of the Wasserstein distance of order 1 to the quantum states of n qudits. Our proposal recovers the classical Wasserstein distance for quantum states diagonal in the canonical basis, hence the distance between vectors of the canonical basis coincides with the Hamming distance. Our distance is invariant with respect to permutations of the qudits and unitary operations acting on one qudit and is additive with respect to the tensor product. Our main result is a continuity bound for the von Neumann entropy with respect to our distance, which significantly strengthens the best continuity bound with respect to the trace distance. We also propose a generalization to quantum observables of the Lipschitz constant for functions, which allows us to compute our distance with a semidefinite program. We prove a quantum version of Marton's transportation inequality and a quantum Gaussian concentration inequality for the spectrum of quantum Lipschitz observables. Moreover, we explore the contraction coefficient with respect to our distance of the n-th tensor power of a one-qudit quantum channel and of shallow quantum circuits. Our distance can have a large impact in quantum information, quantum computation and quantum machine learning, and we discuss several possible applications.

**16:00** Generic aspects of the resource theory of coherence

*Presenter: GRAMEGNA, Giovanni (B)*

The class of incoherent operations induces a pre-order on the set of quantum pure states. We study the maximal success probability of incoherent conversion between pairs of n-dimensional random pure states chosen independently, and find an explicit formula for its large-n asymptotic distribution. Our analysis shows that the statistics of the maximal conversion probability can be determined by the behaviour of the extreme values.

**16:07** Contextuality-by-default for behaviours in compatibility scenarios

*Presenter: TEZZIN, Alisson (University of São Paulo)*

The compatibility-hypergraph approach to contextuality (CA) and the contextuality-by-default approach (CbD) are usually seen as products of entirely different views on how physical measurements and measurement contexts should be understood: the latter is based on the idea that a physical measurement has to be seen as a collection of random variables, one for each context containing that measurement, while the imposition of the non-disturbance condition as a physical requirement in the former precludes such interpretation of measurements. The aim of our work is to show that the main idea behind CbD is already implicit in CA and to introduce in the latter important ideas which arise from the former. We introduce in CA the non-degeneracy condition, which is the analogous of consistent connectedness, and prove that this condition is, in general, weaker than non-disturbance. The set of non-degenerate behaviours defines a polytope, therefore one can characterize non-degeneracy using linear inequalities. We introduce the idea of extended contextuality for behaviours and prove that a behaviour is non-contextual in the standard sense iff it is non-degenerate and non-contextual in the extended sense. Finally, we use extended scenarios and behaviours to shed new light on our results.

**Break (16:15-16:30)**

## Invited: Open Quantum Systems (2 Oct 2020, 16:30-17:15)

Chairperson: Chiara Macchiavello

| time | title |
|---|---|
| 16:30 | Mechanism of decoherene-free coupling between giant atoms<br>*Presenter: CILLUFFO, Dario (Università degli Studi di Palermo, Dipartimento di Fisica e Chimica - Emilio Segrè)*<br>Giant atoms are a new paradigm of quantum optics going beyond the usual local coupling. Building on this, a new type of decoherence-free (DF) many-body Hamiltonians was shown in a broadband waveguide. Here, these are incorporated in a general framework (not relying on master equations) and contrasted to dispersive DF Hamiltonians with normal atoms: the two schemes are shown to correspond to qualitatively different ways to match the same general condition for suppressing decoherence. Next, we map the giant atoms dynamics into a cascaded collision model (CM), providing an intuitive interpretation of the connection between non-trivial DF Hamiltonians and coupling points topology. The braided configuration is shown to implement a scheme where a shuttling system subject to periodic phase kicks mediates a DF coupling between the atoms. From the viewpoint of CMs theory, this shows a collision model where ancillas effectively implement a dissipationless, maximally-entangling two-qubit gate on the system. |
| 16:45 | Decoherence-Free Rotational Degrees of Freedom for Quantum Applications<br>*Presenter: COSCO , Francesco (Ulm University)*<br>Quantum metrology and sensing represent promising near term applications of quantum technologies as they require the control of a few or even single quantum systems. However, a central challenge common to all quantum sensor designs is the necessity to achieve both robustness to environmental noise and, at the same time, high sensitivity to a signal of interest. This task becomes even more challenging when considering massive particles whose translational degrees of freedom are highly susceptible to first order (gradient) fluctuations of external fields, thus inhibiting the generation of long-lived macroscopic quantum superpositions. In this talk, we address this challenge by designing the shape of rigid bodies such that their rotational degrees of freedom can be made robust against decoherence from distant sources, while at the same time allowing for interaction with signals from nearby sources. To this end we introduce a systematic method, based on the mathematical theory of spherical t-designs, to construct rigid bodies whose rotational states are degenerate up to a desired order of the multipole expansion of their energy in a perturbing potential. This allows for the generation of long-lived macroscopic quantum superpositions of rotational degrees of freedom and the robust generation of entanglement between two or more such solids with applications in robust quantum sensing and precision metrology as well as quantum registers. |

17:00 Quantum Zeno and anti-Zeno effect in non-Markovian decay process of single-photon polarization states

*Presenter: VIRZÌ, Salvatore (INRiM, Università di Torino)*

The quantum Zeno effect is a feature of quantum-mechanical systems allowing a system's time evolution to be freezed, or at least slowed down, by measuring the system frequently enough [1-5]. On the contrary, it is also possible to exploit frequent measurements to accelerate the system's evolution, obtaining the quantum anti-Zeno effect. In my presentation, I will describe an experiment investigating quantum Zeno and anti-Zeno effects in the non-Markovian decay process of single-photon polarization states. In our implementation, we simulate a noisy quantum channel exploiting a set of half wave-plates introducing correlated random phase shifts between the vertical and horizontal polarization components. Each phase shift represents a stochastic process defined by a random variable, sampled each time by a specific probability distribution depending on the previous phase shifts (non-Markovian behavior). This stochastic polarization dephasing leads to a decay of the probability to find the system in its initial state. To induce the Zeno effect, we perform repeated measurements by inserting a polarizer between subsequent wave-plates. By controlling the interplay between the application of a sequence of repeated measurements and the probability distribution characterizing the noise of the channel, it is possible to induce on the quantum state both Zeno or anti-Zeno effect. This experiment represents a proof of principle of a technique allowing to control the dynamics of a quantum system in any realistic physical scenario affected by time-correlated noise. In real scenarios, the randomness on the phase can be due to imperfections of the measurement apparatus or to the interaction with an external reservoir, usually entailing non-Markovianity [7] in the observed quantum system.

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**Break (17:15-17:30)**

**Career Panel: Industry (2 Oct 2020, 17:30-18:30)**

Moderator: Marco Barbieri

| time | title |
| --- | --- |
| 17:30 | Career panel: Industry<br>Panelists:<br><br>Matteo Bina (Applied Materials Italia)<br><br>Federico Mattei (IBM)<br><br>Roberto Siagri (Eurotech)<br><br>Niccolò Somaschi (Quandela) |

## Closing remarks (2 Oct 2020, 18:30-18:45)

Iris Agresti, Claudia Benedetti, Mario Collura, Ilaria Gianani, Ugo Marzolino, Francesco Pepe