New trends in complex quantum systems dynamics 2022

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Book of abstracts

Posters, contributed and invited talks

	Monday	Tuesday	Wednesday	Thursday	Friday
09:30 - 10:00	***Sofia Vallecorsa***	***Rainer Blatt***	***Fedor Jelezko***	***Giuseppe Clemente***	***Fernando Luis***
10:00 - 10:30	Daniel Gonzalez-Cuadra	Moshe Goldstein	***Natalia Ares***	Antonio Sannia	Jorge Casanova
10:30 - 11:00	Luca Barbiero	Dmytro Dubyna	Javier Cerrillo	Federico Balducci	Giuseppe Vitagliano
11:00 - 11:30	Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
11:30 - 12:00	***Marcello Dalmonte***	***Hannes Pichler***	***Andreas Schaefer***	***Gary R. Goldstein***	***Mari Carmen Bañuls***
12:00 - 12:30	Simone Notarnicola	Pietro Silvi	Paolo Stornati	Philipp Fabritius	Luca Tagliacozzo
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13:00 - 14:00	Lunch break	Lunch break	Lunch break	Lunch break	Lunch break
14:00 - 14:30	***Alejandro Bermúdez***	***Pepa Martinez-Perez***	***Zohreh Davoudi***	Javier Arguello-Luengo	***Martin Ringbauer***
14:30 - 15:00	**Zala Lenarcic**	Yue Ban	Edgar-Andres Ruiz-Guzman	Guillermo Romero	Robert Trenyi
15:00 - 15:30	Federico Centrone	Marco Cattaneo	Hector Pablo Ojeda Collado	Manuel Pino Garcia	Geza Toth
15:30 - 16:00	Alexander Glazov	Coffee break	Coffee break	Coffee break	
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Invited talks

Extracting the local complexity of quantum dynamics using machine learning

Zala Lenarčič
Jozef Stefan Institute

The vast complexity is a daunting property of generic quantum states that poses a significant challenge for theoretical treatments, especially in non-equilibrium setups. Therefore, it is vital to recognise states which are locally less complex and thus describable with (classical) effective theories.

I will discuss how unsupervised learning can detect the local complexity of states. This approach can be used as a probe of scrambling, hydrodynamics, and thermalisation in chaotic quantum systems or to assign the local complexity in open setups without knowing the corresponding Hamiltonian or Liouvillian. The analysis actually allows for the reconstruction of Hamiltonian operators or even noise-type that might be contaminating the measurements. Since our approach requires only easily accessible local observations, it is an ideal diagnostics tool for data obtained from (noisy) quantum simulators.

Quantum sensing enabled by spin qubits in diamond

Fedor Jelezko
Institute of Quantum Optics, Ulm University, Germany

Single nitrogen vacancy (NV) color centers in diamond currently have sufficient sensitivity for detecting single external nuclear spins and resolve their position within a few angstroms. The ability to bring the sensor close to biomolecules by implantation of single NV centers and attachment of proteins to the surface of diamond enabled the first proof of principle demonstration of proteins labeled by paramagnetic markers and label-free detection of the signal from a single protein. Single-molecule nuclear magnetic resonance (NMR) experiments open the way towards unraveling dynamics and structure of single biomolecules. However, for that purpose, NV magnetometers must reach performance comparable to that of conventional solution state NMR. We will discuss new techniques allowing to combine high spectral resolution and sensitivity in nanoscale NMR. The ability to sense nuclear spins by NV centers also enables the transfer of polarization from optically polarized spins of NV centers to external nuclear spins. Such diamond based techniques for dynamic nuclear spin polarization are very promising for the enhancement of sensitivity of conventional MRI imaging.

Simulating Quantum Field Theories on Quantum Computers in the Light Front Formalism

Gary R. Goldstein
Tufts University

Quantum simulation of quantum field theories offers a new way to investigate properties of the fundamental constituents of matter. We develop quantum simulation algorithms based on the light-front formulation of relativistic field theories. The process of quantising the system in light-cone coordinates will be explained for Hamiltonian formulation, which becomes block diagonal, each block approximating the Fock space with a certain harmonic resolution K. We analyse a Yukawa theory in 1+1D, as well as f4 and a confining NJL model. We show how to compute the analogues of parton distribution functions and form factors of composite particles – hadrons - in these theories. The dependence of such analyses on the scaling of the number of qubits is compared with other schemes and conventional computations. There is a notable advantage to the light-front formulation.

Circuit QED with molecular spin qudits

Fernando Luis
Instituto de Nanociencia y Materiales de Aragón, CSIC-Universidad de Zaragoza, Zaragoza (Spain)

Quantum computing is regarded as the pending scientific revolution of our century, one that will change the way in which we process, secure, and distribute information. Achieving a computational power that can solve practical problems is still very challenging, even for today's most successful platforms, on account of the need of correcting errors and the fact that this requires increasing enormously the number of physical qubits. Artificial magnetic molecules can provide some competitive advantages for progressing towards large-scale quantum computation [1-3]. They are microscopic, thus quantum by nature, yet tuneable, like the circuits but via different methods, based on chemical synthesis. I'll describe with recent examples how to exploit this molecular design to integrate 2, 3, 4 and 6 qubits or, in general, d-dimensional qudits, in individual molecules. These can then act as universal quantum processors and even encode error-corrected qubits. Besides, one also needs a method to wire them up. I'll discuss how to achieve this goal via the coupling to on-chip superconducting resonators, within the realm of circuit quantum electrodynamics experiments.

[1] G. Aromí, D. Aguilà, P. Gamez, F. Luis, and O. Roubeau, Chem. Soc. Rev. 2012, 41, 537.
[2] A. Gaita-Ariño, F. Luis, S. Hill, and E. Coronado, Nature Chem. 2019, 11 301.
[3] S. Carretta, D. Zueco, A. Chiesa, Á. Gómez-León, and F. Luis, Appl. Phys. Lett. 2021, 118, 240501.

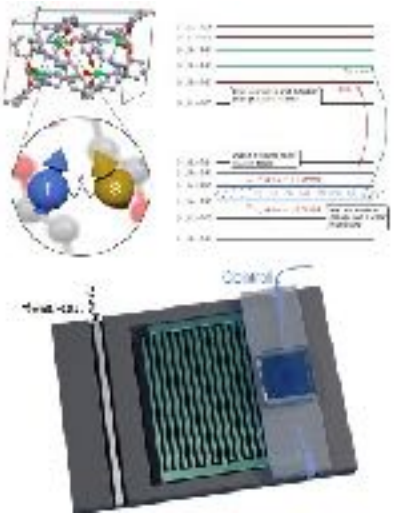

Figure 1. Sketch of a hybrid quantum processor based on molecular spin qudits (here Yb-trensal molecules) coupled to an on-chip superconducting resonator

Data mining the many-body problem - from universal behaviour to Kolmogorov complexity

Marcello Dalmonte
ICTP, Trieste, Italy

Many-body systems are typically characterised via low-order correlation functions, that are directly related to response functions. In this talk, I will show how it is possible to provide a characterisation of many-body systems via a direct and assumption-free data mining of one of the pillars of both classical and quantum statistical mechanics - the partition function. The core idea of this programme is the fact that, once sampled stochastically (such as in experiments with in-situ imaging, or via Monte Carlo simulations), partitions functions can be construed as a very high dimensional manifolds. Such manifolds can be characterised via basic concepts, in particular, by their intrinsic dimension.

I will discuss theoretical results for both classical and quantum many-body spin systems that illustrate how data structures undergo structural transitions whenever the underlying physical system does, and display universal (critical) behavior in both classical and quantum mechanical cases. I will conclude with remarks on the applicability of our theoretical framework to synthetic quantum systems (quantum simulators and quantum computers), and emphasize its potential to provide a direct, scalable measure of Kolmogorov complexity of output states.

Towards quantum simulations with trapped-ion qudits

Martin Ringbauer
UIBK, Innsbruck, Austria

Today's quantum computers and simulators are almost exclusively built for binary information processing. Yet, the underlying quantum information carriers are almost always inherently multilevel systems. Similarly, many quantum simulation applications, in particular lattice gauge theories, are naturally formulated in terms of high-dimensional Hilbert spaces. I will discuss a new universal toolbox for quantum information processing in trapped-ion qudits and it can be used for improved quantum information processing. The qudit approach not only offers intriguing ways to simulate naturally high-dimensional quantum systems. It also offers new ways of performing measurements in standard qubit-based simulators that can drastically reduce the experimental overheads in the characterisation of quantum states and the training of variational circuits.

Quantum computation and quantum simulations with trapped Ca+ ions

Rainer Blatt
UIBK & IQOQI, Innsbruck, Austria

I have intended to present an overview talk about the most recent achievements covering the toolbox, computations, and quantum simulations (analog, digital, hybrid), as well as applications towards quantum metrology and finally, towards quantum error correction.

Towards Extracting the Running Coupling of $(2+1)$-dimensional QED on a Quantum Computer

Giuseppe Clemente
DESY, Zeuthen, Germany

We investigate QED in $(2+1)$ dimensions, which, thanks to the presence of confinement and asymptotic freedom, can be considered as an abelian toy model of QCD. We propose to study the running coupling in the weak and intermediate coupling regimes using quantum computing techniques, with the aim of matching results from Markov Chain Monte Carlo at strong coupling.
This would allow us to obtain the physical value of the lattice spacing and, in turn, provide a physical scale for the running coupling. Our analysis method can be generalised to similar asymptotically free lattice quantum field theories.

Decoherence and Thermalisation in Heavy Ion Collisions

Andreas Schaefer
Regensburg University, Germany

Whether and how an isolated many particle quantum system can thermalise for a T-reversal invariant interaction like QED and QCD is a highly relevant question for many fields of physics. The collision of two heavy nuclei in the vacuum of a beam pipe provides an especially clean environment to study it. We try to combine insights from AdS/CFT, black hole physics, lattice QCD, hydrodynamics and condensed matter physics to explain data obtained by LHC and RHIC experiments. This results in additional questions for future research.

Long-range Ising models: Probing the renormalisation of sound in non-perturbative QFTs with crystals of trapped ions

Alejandro Bermudez
UAM / IFT, Spain

Trapped-ion crystals have proved to be neat quantum simulators for the quantum Ising model, where the spin-spin interactions are mediated by the vibrational phonons of the crystal (Gaussian field). In the vicinity of a certain structural phase transition, one must consider higher-order non-linearities, which give rise to phonon-phonon interactions and upgrade the Gaussian field into a \lambda \phi^4 quantum field theory (QFT). In this talk, I will discuss how the (non-perturbative) properties of this paradigmatic QFT can be probed by measuring the corrections to the long-range decay of the Ising spin-spin interactions, and discuss interesting consequences of finite temperatures, such as the role of thermal masses and symmetry restoration.

Quantum Machine Learning in High Energy Physics: examples at CERN

Sofia Vallecorsa
CERN, Switzerland

CERN has recently started its Quantum Technology Initiative in order to investigate the use of quantum technologies in High Energy Physics (HEP). A three-year roadmap and research programme has been defined in collaboration with the HEP and quantum-technology research communities. In this context, initial pilot projects have been set up at CERN in collaboration with other HEP institutes worldwide on Quantum Computing and Quantum Machine Learning in particular. These projects, are studying basic prototypes of quantum algorithms, which are being evaluated in the context of LHC experiments for different types of workloads. This talk will provide an overview of recent results obtained by the different studies, including applications in areas ranging from accelerator beams optimisation to data analysis and classification.

Machine learning for the real time control of quantum devices

Natalia Ares
Oxford University, UK

Machine learning has been the enabler of well-known breakthroughs in computer science, such as the victory of Alpha Go over a Go world champion and superhuman face recognition. We can direct this potential to the characterisation and tuning of quantum devices in real time. As in Go, where a player must carefully balance short and long-term goals and devise actions accordingly, we have demonstrated a deep reinforcement learning algorithm that devises efficient policies to find desired measurement features. Our algorithm divides the parameter space of a semiconductor quantum device in blocks, and finds target measurement features by performing a minimum number of block measurements. In this way, we reduce the long characterisation times required due to device variability.

We have also developed an algorithm that measures bias triangles, important features for qubit operation, and gives them a score. The device parameters are then updated to optimise this score in real-time. The algorithm, using a disentangling variational auto-encoder, proves capable of fine-tuning several device parameters at once. I will also show automatic identification of Pauli spin blockade. To conclude, I will demonstrated an algorithm able to tune a double quantum dot device regardless of the semiconductor realisation. These approaches are widely applicable, opening the way to a completely automatic and efficient route to quantum device tuning and characterisation, and thus taking a crucial step towards the scalability of quantum circuits.

Entanglement-Optimal Trajectories of Many-Body Quantum Markov Processes

Hannes Pichler
UIBK & IQOQI, Innsbruck, Austria

In this talk I present a method to solve the equations of motion of open quantum many-body systems. It is based on a combination of generalised wave function trajectories and matrix product states. More specifically, we developed an adaptive quantum stochastic propagator, which minimises the expected entanglement in the many-body quantum state, thus minimising the computational cost of the matrix product state representation of quantum trajectories. I illustrate this approach on the example of one-dimensional open Brownian circuit: First, I show that this model displays an entanglement phase transition between area and volume law when changing between different propagators and then I show that our method autonomously finds an efficiently representable area law unravelling.

Tatiana Vovk and Hannes Pichler, Physical Review Letters 128, 243601(2022)

Finite energy properties with tensor networks and quantum devices

Mari Carmen Bañuls
MPQ, Garching, Germany

Ground state and thermal equilibrium properties of local quantum many-body systems can be explored with tensor networks, thanks to their area law entanglement. But highly excited states or out-of-equilibrium setups are much harder. These are therefore the natural problems in which quantum devices can potentially find the earliest advantage.

Energy filters allow us to access properties of the system at finite energy densities. They can be efficiently realised by quantum simulators or computers, which simulate the quantum dynamics, combined with classical filtering and sampling. But also replacing the quantum evolution by its classical simulation with tensor networks provides a new tool to classically compute dynamical properties of much larger systems than allowed by other methods.

Contributed talks

Topological Properties of Dipolar Quantum Simulators

Luca Barbiero
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Quantum simulators made of magnetic atoms allow to investigate intriguing topological states of matter. In the case of bosonic atoms we show that the combination of topology and quantum criticality can give rise to an exotic mix of counterintuitive effects. In particular, we reveal the presence of two distinct topological quantum critical points with localised edge states and gapless bulk excitations. Our results demonstrate that the topological critical points always separate two phases, one topologically protected and the other topologically trivial, both characterised by a long-range ordered string correlation function. In the case of fermionic dipolar quantum simulators, we uncover a topological sector which remained elusive in previous finite-size numerical studies due to boundary effects. We first show that, for an infinite system, the bond order wave regime is characterised by two degenerate bulk states corresponding to the trivial and topological sectors. At the same time, for finite size systems, we show that the topological sector can be stabilised by imposing a suitable border potential. Finally I will discuss how all such topological orders can be detected with a quantum gas microscope.

J. Fraxanet, D. González-Cuadra, T. Pfau, M. Lewenstein, T. Langen, and L. Barbiero Phys. Rev. Lett. 128, 043402 (2022)

S. Julià-Farré, D. González-Cuadra, A. Patscheider, M. J. Mark, F. Ferlaino, M. Lewenstein, L. Barbiero, and A. Dauphin arXiv:2112.08785

Cooperative subwavelength molecular emitter arrays

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Sub-wavelength quantum emitter arrays exhibit a cooperative response to external light fields allowing them to be utilised as strongly reflective metasurfaces, platforms for topological quantum optics or to be employed in design of nanoscale coherent light sources. Sub-wavelength separations could be realised in molecular ensembles, where radiative properties are strongly susceptible to vibrionic effects such as electron-vibron couplings as well as vibrational relaxation. We provide here analytical and numerical results showing the modification of standard radiative properties such as sub- and super-radiance in arrays of molecules. Surprisingly, we find that the typically detrimental effect of vibrational relaxation can lead to the generation of purely electronic entanglement in molecular dimers. Finally, we analytically and numerically provide results for the emission properties of molecular nano-rings acting as coherent light sources.

Note: This work is in the process of being finished and I expect that it will be published when the conference starts.

Nanoscale Coherent Light Source. Raphael Holzinger, David Plankensteiner, Laurin Ostermann, and Helmut Ritsch. Phys. Rev. Lett. 124, 253603 – Published 26 June 2020

Cooperative Quantum Phenomena in Light-Matter Platforms. Michael Reitz, Christian Sommer, and Claudiu Genes. PRX Quantum

Langevin Approach to Quantum Optics with Molecules. Michael Reitz, Christian Sommer, and Claudiu Genes. Phys. Rev. Lett. 122, 203602 – Published 20 May 2019

Quantum simulation of dissipative collective effects on noisy quantum computers

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Dissipative collective effects are ubiquitous in quantum physics, and their relevance ranges from the study of entanglement in biological systems to noise mitigation in quantum computers. Here [1], we put forward the first fully quantum simulation of dissipative collective phenomena on a real quantum computer. The quantum simulation is based on the recently introduced multipartite collision model [2], which reproduces the action of a dissipative common environment by means of repeated interactions between the system and some ancillary qubits. First, we theoretically study the accuracy of this algorithm on near-term quantum computers with noisy gates, and we derive some rigorous error bounds that depend on the timestep of the collision model and on the gate errors. These bounds can be employed to estimate the necessary resources for the efficient quantum simulation of the collective dynamics. Then, we implement the algorithm on some IBM quantum computers to simulate superradiance and subradiance between a pair of qubits. Our experimental results successfully display the emergence of collective effects in the quantum simulation. In addition, we analyze the noise properties of the gates we employed in the algorithm by means of full process tomography, with the aim of improving our understanding of the errors we run into using the near-term devices that are currently accessible to worldwide researchers. We obtain the values of the average gate fidelity, unitarity [3], incoherence and diamond error [4], and we establish a connection between them and the accuracy of the experimentally simulated state. In particular, we build a noise model based on the results of the process tomography for two-qubit gates and show that its performance is comparable with the noise model provided by IBM, which also takes into account noisy single-qubit gates and local relaxation; however, our noise model may overperform the IBM one in the presence of some very noisy gates. Finally, we observe that the scaling of the error as a function of the number of gates is favorable, but at the same time reaching the threshold of the diamond errors for quantum fault tolerant computation may still be orders of magnitude away.

[1] M. Cattaneo, M. A. C. Rossi, G. Garc´ıa-P´erez, R. Zambrini, and S. Maniscalco, Quantum simulation of dissi- pative collective effects on noisy quantum computers, preprint arXiv:2201.11597 (2022).

[2] M. Cattaneo, G. De Chiara, S. Maniscalco, R. Zambrini, and G. L. Giorgi, Collision Models Can Efficiently Simulate Any Multipartite Markovian Quantum Dynamics, Phys. Rev. Lett. 126, 130403 (2021).

[3] J. Wallman, C. Granade, R. Harper, and S. T. Flammia, Estimating the coherence of noise, New J. Phys. 17, 113020 (2015).

[4] J. Watrous, The Theory of Quantum Information (Cambridge University Press, 2018).

Interacting Topological Insulators and their connection to high-energy physics

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Understanding the robustness of topological phases of matter in the presence of strong interactions is a difficult challenge of modern theoretical physics. In this talk, I will describe the imbalanced Creutz-Hubbard ladder, a paradigmatic topological-insulator model that can be realised in a synthetic ladder made of two internal states of ultra-cold fermionic atoms in a one-dimensional optical lattice. Using numerical approach based on MPS algorithms, I will discuss its phase diagram, and the interesting connections to high-energy physics Gross-Neveu model in (1+1) dimension, and open an interesting dialogue between both disciplines.
Finally I will discuss the connections between correlated Chern insulators and strongly-coupled four-Fermi field theories that are related to the Gross-Neveu model in (2+1) dimensions. I will show the the large- N study, I have developed to understand the Gross-Neveu phase diagram and their numerical benchmark via PEPS methods.

[1] A. Bermudez, E. Tirrito, M. Rizzi, M. Lewenstein, S. Hands, Annals of Physics 399, 149 (2018)

[2] L. Zigler, E. Tirrito, M. Lewenstein, S. Hands, A. Bermudez, arXiv:2011.08744 (2020)

[3] L. Zigler, E. Tirrito, M. Lewenstein, S. Hands, A. Bermudez, Annals of Physics 499, 168763 (2022)

[4] E. Tirrito, M. Lewenstein, A. Bermudez, arxiv:2112.07654 (2021)

Digital quantum simulation of non-abelian gauge theories using programmable Rydberg qudits

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Non-abelian gauge theories underlie our understanding of fundamental forces in nature, and developing tailored quantum hardware and algorithms to simulate general quantum gauge field theories is an outstanding challenge in the rapidly evolving field of quantum simulation. In this talk, I will present an approach where gauge fields, discretised in space and time, are represented by qudits, and are time-evolved in Trotter steps with multi-qudit quantum gates. This maps naturally and hardware-efficient to an architecture based on Rydberg tweezer arrays, where long-lived internal atomic states represent qudits, and the required quantum gates are performed as error-tolerant holonomic operations supported by a Rydberg blockade mechanism. I will illustrate the proposal for a minimal digitisation of SU(2) gauge fields, where I will also show how to verify the quantum simulation using Hamiltonian learning techniques.

Optomechanical strong coupling between a single photon and a single atom

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Single atoms coupled to a cavity offer unique opportunities as quantum optomechanical devices because of their small mass and strong interaction with light. A particular regime of interest in optomechanics is that of 'single-photon strong coupling', where motional displacements on the order of the zero-point uncertainty are sufficient to shift the cavity resonance frequency by more than its linewidth. In many cavity QED platforms, however, this is unfeasible due to the large cavity line-width [1,2]. Here, we propose an alternative route in such systems, which instead relies on the coupling of atomic motion to the much narrower cavity-dressed atomic resonance frequency. We discuss and optimise the conditions in which the scattering properties of single photons from the atom-cavity system become highly entangled with the atomic motional wave function. We also analyse the prominent observable features of this optomechanical strong coupling, which include a per-photon motional heating that is significantly larger than the single-photon recoil energy, as well as mechanically induced oscillations in time of the second-order correlation function of the emitted light [3]. This physics should be realizable in current experimental setups, such as trapped atoms coupled to photonic crystal cavities, and more broadly opens the door to realising qualitatively different phenomena beyond what has been observed in optomechanical systems thus far.

[1] P. Samutpraphoot, et al., Phys. Rev. Lett. 124, 063602 (2020).

[2] D. Niemietz, P. Farrera, S. Langenfeld, G. Rempe. Nature 591 (7851), 570 (2021).

[3] J. Argüello-Luengo, D.E. Chang. New J. Phys. 24 023006 (2022).

Multi-copy metrology with many-particle quantum states

Robert Trenyi
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In [1], we consider quantum metrology with several copies of bipartite and multipartite quantum states. We identify a large class of entangled states that become maximally useful for metrology in the limit of infinite number of copies. The maximally achievable metrological usefulness is attained exponentially fast in the number of copies. We show that, on the other hand, pure entangled states with even a small amount of white noise do not become maximally useful even in the limit of infinite number of copies. We also make general statements about the usefulness of a single copy of pure entangled states. We show that the multiqubit states presented in Hyllus et al. [Phys. Rev. A 82, 012337 (2010)], which are not more useful than separable states, become more useful if we embed the qubits locally in qutrits. We discuss the relation of our scheme to error correction, and possible use for quantum information processing in a noisy environment.

[1] R. Trényi, Á. Lukács, P. Horodecki, R. Horodecki, T. Vértesi, and G. Tóth, arXiv:2203.05538 (2022).

Periodically refreshed quantum thermal machines

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We introduce unique class of cyclic quantum thermal machines (QTMs) which can maximise their performance at the finite value of cycle duration where they are most irreversible. These QTMs are based on single-stroke thermodynamic cycles realised by the non-equilibrium steady state (NESS) of the so-called Periodically Refreshed Baths (PReB) process. We find that such QTMs can interpolate between standard collisional QTMs, which consider repeated interactions with single-site environments, and autonomous QTMs operated by simultaneous coupling to multiple macroscopic baths. We discuss the physical realisation of such processes and show that their implementation requires a finite number of copies of the baths. Interestingly, maximising performance by operating in the most irreversible point as a function of cycle duration comes at the cost of increasing the complexity of realising such a regime, the latter quantified by the increase in the number of copies of baths required. We demonstrate this physics considering a simple example. We also introduce an elegant description of the PReB process for Gaussian systems in terms of a discrete-time Lyapunov equation. Further, our analysis also reveals interesting connections with Zeno and anti-Zeno effects.

Archak Purkayastha, Giacomo Guarnieri, Steve Campbell, Javier Prior, John Goold, arXiv:2202.05264 (2022).

A randomised measurement toolbox for Rydberg quantum technologies

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Recent experimental advances have allowed the realisation of quantum simulators at unprecedented sizes and levels of control. These achievements have led to the implementation of nontrivial quantum many-body states on different platforms, such as superconducting qubits, trapped ions, and Rydberg atom lattices. Once a target state has been prepared, inferring its peculiar quantum properties, such as its entanglement, represents a challenge in terms of the required number of measurements that are needed and the protocol complexity.
I will present a toolbox to investigate quantum many-body states implemented on a Rydberg-atom quantum simulator by exploiting randomised measurements. I will show the efficacy of this measurement toolbox to measure entanglement, via the estimation of the purity, and to verify a ground-state preparation by measuring the Hamiltonian variance. I will show a protocol to realise independent, local unitary rotations, which are the fundamental ingredient to implement random independent measurements. As an application, I will discuss the case of the one-dimensional SSH model, recently realised on a chain of Rydberg atoms, probing the entanglement for different partitions and the ground state preparation process.

S. Notarnicola, A. Elben, T. Lahaye, A. Browaeys, S. Montangero, B. Vermersch, arXiv:2112.11046, 2021

Scalable digital quantum simulation of lattice fermion theories

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We discuss a platform-neutral, general strategy to perform the quantum simulation of any quantum fermionic theory on a lattice, under open boundary conditions. The quantum simulator is digital, as it employs solely one- and two-qubit gates, and scalable, since integrating each Hamiltonian term requires a finite (non-scaling) cost. Our strategy relies on $\mathbb{Z}_2$ auxiliary lattice gauge fields which make the fermion theory genuinely local without changing its dynamics. We show that such mapping to a lattice gauge theory is also useful in Tensor Network numerical simulations.

Physical properties of an Abelian lattice gauge theory at finite winding density

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We explore the physics of Abelian gauge theories without dynamical matter fields in finite background electric fields. We consider the $U(1)$ gauge-invariant quantum link model realised with spin-$1/2$ gauge fields, and a two-dimensional local Hilbert space. Using the density matrix renormalisation group (DMRG) algorithm implemented on a ladder system, we study the condensation phenomena in the ground state as a function of a uniform background flux introduced into the system through the boundary. We study how the electric flux tubes arrange themselves in the bulk giving rise to different phases.

Analog Quantum Simulation of Topological Lattice Models with a Parametric Cavity

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There has been a growing interest in developing quantum simulators for physical systems where perturbative methods are ineffective. The scalability and flexibility of circuit quantum electrodynamics (cQED) make it a promising platform for various types of simulators, including lattice models of strongly coupled field theories. Here, we use a multimode superconducting parametric cavity as a hardware-efficient analog quantum simulator, realising a lattice in synthetic dimensions with complex hopping interactions. The coupling graph, i.e., the simulated model, can be programmed in situ. Manipulating complex-valued hopping interactions, we can simulate, for instance, gauge potentials and topological models. As a demonstration, we simulate paradigmatic topological models including the bosonic Creutz ladder and Su-Schrieffer–Heeger (SSH) model. We characterise the lattice with scattering measurements, reconstructing the experimental Hamiltonian and observing important precursors of topological features including nonreciprocal transport and Aharonov-Bohm caging. This platform can be easily extended to larger lattices and different models involving other interactions.

D. Dubyna, J.H. Busnaina, Z. Shi, J. S.C. Hung, I. Nsanzineza, C.M. Wilson. Institute for Quantum Computing and Department of Electrical and Computer Engineering, University of Waterloo, Waterloo, Ontario N2L 3G1, Canada

The role of dissipation in Quantum Reservoir Computing

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Reservoir computing is an unconventional computing approach used to solve temporal and non-linear tasks typically faced by recurrent neural networks [1]. According to this paradigm, a generic input signal influences the dynamics of a non-linear system (the reservoir) while the corresponding output is given by a linear transformation of the reservoir's observables. The advantage of this scheme is that its training stage only consists in a linear optimisation of the readout without influencing the properties of the reservoir. Consequently, it will require a relatively small training data set and computational resources. Recently, quantum systems have been proposed to physically implement this paradigm. At the moment the most studied theoretical quantum model is based on a spin network and was originally proposed by Fuji and Nakajima [2]. It has been verified in several benchmark tests showing promising results. However, this model is hard to be experimentally implemented and a particular problem is given by the assumption that the spin network evolves as a closed system between input injections. In this work [3], we will exploit the possibility to consider the spin network as an open quantum system [4]. First of all, we will show how a dissipation approach is able to reproduce the model in [2]. Finally, we propose and characterise a new model described by a Lindblad master equation able to outperform the previous ones in terms of linear/non-linear memory and time series forecasting. In this model, the input is injected into the system through an external drive which modifies the Hamiltonian dynamics.

[1] Mantas Lukoševičius, Herbert Jaeger.Reservoir computing approaches to recurrent neural network training. Computer Science Review, Volume 3, Issue 3 (2009).

[2] K. Fujii and K. Nakajima. Physical Review Applied, 8(2):024030, 2017.

[3] Antonio Sannia, Rodrigo Martínez-Peña, Miguel C. Soriano, Gian Luca Giorgi, Roberta Zambrini. The role of dissipation in Quantum Reservoir Computing (in progress)

[4] Breuer, H., & Petruccione, F.(2007-01-25).The Theory of Open Quantum Systems.: Oxford University Press.

Optimal control of a quantum sensor: A fast algorithm based on an analytic solution

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Quantum sensors can show unprecedented sensitivities, provided they are controlled in a very specific, optimal way. In this talk, I will consider a spin sensor of time-varying fields in the presence of dephasing noise, and show that the problem of finding the optimal pulsed control field can be mapped to the determination of the ground state of a spin chain. I will discuss an approximate, analytic solution of this problem, which provides a lower bound for the sensor sensitivity, and a pulsed control sequence very close to optimal. Such sequence can be further improved via a fast simulated annealing algorithm. I will finally show a comparison with experimental data, to demonstrate the sensitivity improvement for a spin-qubit magnetometer based on a nitrogen-vacancy (NV) center in diamond, and sketch some possible applications of our protocol.

Hernández-Gómez et al, arXiv:2112.14998

Dissipation in superfluid transport through an atomic quantum point contact

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We report on the effects of spin-dependent and spin-independent dissipation on the non-linear superfluid transport of a strongly interacting Fermi gas through a quantum point contact (QPC). Using shaped light we can create almost arbitrary potential landscapes for the atoms as well as effective magnetic fields and dissipation channels to alter and probe their transport. We introduce spin selective dissipation via an optical tweezer inside a QPC by tuning the laser to a weak line only addressing one of the constituents of the unitary Fermi gas, for spin-independent dissipation we address a molecular line. The dissipation has a strong effect on the transport of the superfluid changing it from nonlinear to linear. In addition the spin-dependent dissipation introduces a spin-current which allows us to study the coupling between spin and particle currents in the strongly interacting regime. These results open the way to studying the coupling of particle, heat and spin transport in an atomic quantum point contact.

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Tensor Network Simulations of Holographic Quantum Error Correction and Conformal Field Theory

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In recent years, tensor network simulations have been utilised to study quantum critical spin systems, in addition to notions of quantum error correction. Two excellent examples of each of these research directions involve the multi-scale entanglement renormalisation ansatz (MERA) and the holographic quantum error correction codes (HaPPY). In this talk, I will discuss recent work in order to combine the variational expressivity of MERA for describing quantum systems at or near a critical point, with notions of holographic QEC arising from toy models of the AdS/CFT correspondence. In particular, we shall focus on recent work and current projects related to the so-called hyper-invariant tensor networks.

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Minimal Time and Quantum Speed Limit for Effective Self-Similar Expansion of Bose Gases

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Effective scaling approach, producing an auxiliary equation for the scaling parameter interpolating between the non-interacting and the Thomas-Fermi limits, allows us to design the shortcuts to adiabatic expansion of trapped Bose gases for arbitrary values of interaction. Bonding the possible frequency, we adopt Pontryagin's maximum principle to find the time-minimal solutions of bang-bang protocol. This coincides with the maximum speed limit allowed by quantum evolution, and further imply the exponential bounds in the quest for absolute zero, in quantum refrigerator cycles, under the influence of atomic interactions.

A Neural Network Assisted 171Yb+ Quantum Magnetometer

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A versatile magnetometer should deliver a readable response when exposed to targets fields in a wide range of parameters. In this work, we experimentally demonstrate a hybrid approach that combines a 171Yb+ atomic sensor and an adequately trained neural network [1] able to characterise with high precision target fields in distinct challenging scenarios. In particular, we estimate parameters of radio frequency (RF) drivings with a large shot noise including the limiting case of continuous data acquisition with single-shot measurements, and in regimes where the sensor delivers a response that significantly departs from the standard harmonic behaviour [2].

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Dynamical decoupling techniques and complex systems

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Quantum Sensing with nitrogen-vacancy (NV) centers in diamond promises to revolutionise detection and imaging techniques. Via the adequate application of suited radiation patterns over NVs, one can increase spectral resolution up to a level that enables the detection of complex systems in different scenarios such as those involving large static magnetic fields. In this talk I will explain distinct quantum control protocols based on dynamical decoupling techniques, and their combination with data processing methods for technological applications such as imaging at the micro-scale and nano-scale, the interpretation of non-harmonic responses in atomic size detectors, or the identification of electron spin labels in biomolecules.

Spin squeezing and entanglement quantification in atomic gases

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I will present some recent results on entanglement detection and quantification with collective spin measurements in many-body ensembles. After a brief review of the idea of “Spin Squeezing” and its relation with multipartite entanglement [1][2][3][4][5], I will focus on the quantification of entanglement by means of entanglement monotones with spin squeezing methods [6]. I will consider broad families of entanglement criteria that are based on variances of arbitrary operators and analytically derive the lower bounds these criteria provide for two relevant entanglement measures: the best separable approximation (BSA) and the generalised robustness (GR). As a concrete application, I will show the results of applying this method with experimental data of a spin-squeezed Bose-Einstein condensates of ~ 500 atoms.

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Photon-Instanton Collider Implemented by a Superconducting Circuit: Splitting a Single Photon

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How would our world look like if the fine structure constant α were of order unity? While in our small α world an atom excited to the first excited state has negligible probability of decaying to the ground state while emitting more than a single photon, such processes are important in a large α world, making photon frequency conversion effective in the single-photon regime. We show how such behaviour can be realised in a superconducting circuit QED system, where a transmon, which serves as an artificial atom, is galvanically coupled to a high-impedance Josephson junction array, which acts as a waveguide for microwave photons with a high effective α. Instantons (phase slips) that occur in the transmon interact with the microwave photons, and lead to inelastic scattering probabilities which approach unity and greatly exceed the effect of the quartic anharmoncity of the Josephson potential [1]. The instanton-photon cross section is calculated using a novel formalism which allows to directly observe the dynamical properties of the instantons, and should be useful in other quantum field theoretical contexts. The calculated inelastic decay rates compare well with recent measurements from the Manucharyan group at Maryland [2]. I will also show how this effects can be used to shed a single-photon light on the Bulgadaev-Schmid superconductor-to-insulator transition in the transmon, which has been the center of a recent controversy.

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Phys. Rev. Lett. 126, 197701 (2021) - Inelastic Scattering of a Photon by a Quantum Phase Slip (aps.org)

Uncertainty relations with the variance and the quantum Fisher information

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We present several inequalities related to the Robertson-Schrödinger uncertainty relation. In all these in- equalities, we consider a decomposition of the density matrix into a mixture of states, and use the fact that the Robertson-Schrödinger uncertainty relation is valid for all these components. By considering a convex roof of the bound, we obtain an alternative derivation of the relation in Fröwis et al. [Phys. Rev. A 92, 012102 (2015)], and we can also list a number of conditions that are needed to saturate the relation. We present a formulation of the Cramér-Rao bound involving the convex roof of the variance. By considering a concave roof of the bound in the Robertson-Schrödinger uncertainty relation over decompositions to mixed states, we obtain an improvement of the Robertson-Schrödinger uncertainty relation. We consider similar techniques for uncertainty relations with three variances. Finally, we present further uncertainty relations that provide lower bounds on the metrological usefulness of bipartite quantum states based on the variances of the canonical position and momentum operators for two-mode continuous variable systems. We show that the violation of well-known entanglement conditions in these systems discussed in Duan et al. [Phys. Rev. Lett. 84, 2722 (2000)] and Simon [Phys. Rev. Lett. 84, 2726 (2000)] implies that the state is more useful metrologically than certain relevant subsets of separable states. We present similar results concerning entanglement conditions with angular momentum operators for spin systems.

Accessing ground-state and excited-state energies in a many-body system after symmetry restoration using quantum computers

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We explore the possibility to perform symmetry restoration with the variation after projection technique on a quantum computer followed by additional post-processing. The final goal is to develop configuration interaction techniques based on many-body trial states pre-optimised on a quantum computer. We show how the projection method used for symmetry restoration can prepare optimised states that could then be employed as initial states for quantum or hybrid quantum-classical algorithms. We use the quantum phase estimation and the quantum Krylov approaches for the post-processing. The latter method combined with the quantum variation after projection leads to very fast convergence toward the ground-state energy. The possibility to access excited states energies is also discussed. Illustrations of the different techniques are made using the pairing Hamiltonian.

[1] Ruiz Guzman, E. A., & Lacroix, D. (2022). Accessing ground-state and excited-state energies in a many-body system after symmetry restoration using quantum computers. Phys. Rev. C, 105(2), 24324. https://doi.org/10.1103/PhysRevC.105.024324

Universality at an out of equilibrium

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I will review the role of universality at equilibrium and its effect on approximate simulations with tensor networks and quantum circuits. This will motivate our quest for identifying the universal properties of systems out of equilibrium where those simulations techniques are harder to apply. In that context, I will discuss some features of universal entanglement spectra for the Ising and Potts model in 1+1D.

The Third Level: NV-centers, Andreev Spin Qubits and Trapped Ions

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In this talk I will present three recent experiments on quantum systems where the involvement of a third level in its control protocol has been crucial to open a new avenue for exploitation in computation, sensing or communication.

First, NV-centers in nano-diamonds, which can be used as highly accurate nanoscale sensors, fail to respond to microwave control pulses at low local magnetic fields. With the design of an effective Raman coupling (ERC) [1], it is possible to circumvent this limitation. The ERC can be achieved by adjustment of the microwave frequency to that of the zero-field line and judicious timing of the pulses, such that the full potential of the spin-1 ground state is put to work. The technique has been recently implemented experimentally [2], paving the way for low-field detection of biomolecules.

Second, Josephson weak links are known to host Andreev quasiparticles. Their high localisation and built-in protection against charge noise makes their spin extremely appealing as registers for quantum information. Nevertheless, their implementation was not possible due to the lack of direct control of the spin state. Thorough analysis of the level structure and the implementation of techniques stemming from quantum optics made it clear that the use of high-lying Andreev modes could be used as intermediaries for the coherent control of spin [3]. The final demonstration of such approaches came recently [4] and constitutes groundbreaking progress towards scalable solid-state quantum computers.

Finally, trapped ions have long established themselves as accurate and reliable platforms for quantum information processing. Their operation relies on laser cooling preparation steps, which can be substantially improved by the use of electromagnetically-induced transparency [5]. These techniques are flexible and can be designed for complex level structures, as recently shown in quantum-clock experiments [6]. Quantum mass spectrometry experiments will benefit strongly from their implementation [7].

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Fractional resonances and prethermal states in Floquet systems

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In periodically driven quantum systems, resonances can induce exotic non-equilibrium behaviour and new phases of matter without static analog. We report on the emergence of fractional and integer resonances in a broad class of many-body Hamiltonians with a modulated hopping with a frequency that is either a fraction or an integer of the parameter that characterises the on-site anharmonic spectrum. We contend that there is a fundamental difference between these resonances when interactions bring the system to a Floquet pre-thermal state. In the fractional resonance case, second-order processes dominate the dynamics, leading to less entanglement and more localised quantum states than in the integer resonance case dominated by first-order processes. We quantify this using the von Neumann entropy and Loschmidt echo of quantum states. Our findings reveal novel features of the non-equilibrium quantum many-body system such as the coexistence of Floquet pre-thermalisation and localisation, that may allow to develop quantum memories for quantum technologies and quantum information processing.

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The capacitive coupling of persistent current qubits

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Persistent current qubits are usually coupled to other elements via magnetic interactions. However, those interactions alone are only able to reproduce a small family of interacting models. In order to enlarge this family, we have analysed the capacitive coupling between persistent current devices. First, we present a general theory to find the effective interaction in the computational subspace, which works even in the ultra-strong coupling regime. Then, we investigate three superconducting circuits designs that, thanks to the capacitive coupling, can emulate relevant low-energy Physics. The first one is a persistent-current qubit coupled to an LC resonator. We have found that, by adding standard magnetic coupling, this system can simulate unexplored regimes of light-matter interactions. The second design corresponds to two flux qubits joined via a capacitor. By adding magnetic interactions again, it displays an ultra-strong non-stoquastic low-energy Hamiltonian. In the last case, we explore a fluxonium qutrit capacitively coupled to a waveguide, which contains a quasi bound-state in the continuum with extremely long decaying times."

Emergent Dynamical Phases in a Periodically Driven BCS systems

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We study the out-of-equilibrium dynamics of a BCS system subject to a periodic drive in a wide range of frequencies and drive strengths, in the absence and presence of dissipation. The phase diagram is surprisingly rich, with four dynamical phases involving first and second-order type transitions. For excitation frequency above the gap, we show the emergence of a new collective mode, dubbed Rabi-Higgs [1] which turns into a gapless regime following a second-order phase transition. In the presence of dissipation, the Rabi-Higgs mode becomes a transient effect and interesting steady-states with strong nonlinearities appear [2]. On the other hand, for sub-gap excitation, we demonstrate that the combined effect of drive and interactions results in emerging parametric resonances, analogous to a vertically driving pendulum [3]. In particular, Arnold's tongues appear when the driving frequency matches $2\Delta 0/n$, with n being a natural number and $\Delta 0$ the equilibrium gap parameter. Inside Arnold's tongues, we find a commensurate time-crystal condensate that retains the U(1) symmetry breaking of the parent superconducting phase and shows an additional time-translational symmetry breaking. Outside the tongues, the synchronised collective Higgs mode found in quench protocols [4] is stabilised without the need for a strong perturbation. We show the parametric resonances are quite robust and do not need long coherence times to be observed. Our results are directly relevant to cold-atom and condensed-matter systems and may have applications in parametric amplification, frequency converters, and sensing.

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Cost and routing in Continuous Variables quantum networks

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In this work we present new methods and results to study continuous-variable graph states with regular and complex topologies. Continuous-variable (CV) describes quantum states living in infinite dimensional Hilbert spaces and is the most natural language for bosonic fields, such as photons. Moreover, generation and measurement of CV states requires only coherent control on classical laser source and weakly non-linear materials, along with coherent (homodyne) detection which, differently from photon counting detectors, can be highly efficient at room temperature and easily integrated in classical communication networks. CV graph states are of particular significance in the theory of continuous variable quantum information, in particular in their quantum optical implementations. They are in fact resources for measurement-based quantum computing, quantum simulations, multi-party quantum communication and quantum metrology.

Our model aims at reproducing the existing photonic platforms with realistic experimental constraints, such as limited amount of squeezing, while, at the same time, probing their capabilities while the scaling of the network increases beyond the capacities allowed by the state-of-the-art technology. Since, as we said, the main limitation to construct these optical systems is finite squeezing, we provide an analytical formula that allows to compute the amount of squeezing in each mode as a function of the spectrum of the underlying graph. We show the cost of graph states as a global measure of squeezing and number of squeezed modes that are necessary to build the network. In particular we explore the cost of different networks topologies in term of number of needed squeezers at fixed number of nodes in the networks and of the global amount of squeezing.

We then explore their potentialities to perform efficient quantum information processing between two arbitrary nodes when assisted with a given class of Gaussian Local Operations and Classical Communication (GLOCC) by all the agents in the network. We analytically show an interesting effect, namely that, in some specific topologies, homodyne measurements along parallel paths allow to increase the entanglement between two distant nodes. Finally, we devise a routing protocol based on local quadrature measurements for reshaping the network in order to perform teleportation protocol between two arbitrary nodes of the networks.

Quantum B tagging for B-meson factories

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B-factories, electron-positron particle accelerators operating at the Y(4S) energy are uniquely suited for studies of quantum coherence effects in the BBbar mesons system and for searches of rare and forbidden decays in the Standard Model of particle physics. One of the challenges in the data analysis is to assign (“tag”) the reconstructed B decay products to the correct B mesons. A novel quantum tagging method is proposed here which is tested on a toy data sample, that promises a higher efficiency compared to the standard machine-learning approaches.

Posters

Numerical studies of collective super-radiant emission of light in large inhomogeneous atomic ensembles

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Theoretical studies of super-radiant lasing on optical clock transitions predict a superb frequency accuracy and precision closely tied to the bare atomic line-width [1]. Such a super-radiant laser is also robust against cavity fluctuations when operated in a bad-cavity regime. Recent predictions suggest that this unique feature persists even for a hot and thus strongly broadened ensemble, provided the effective atom number is large enough. Here we use a second-order cumulant expansion approach to study the power, line-width and line-shifts of such a super-radiant laser as a function of the inhomogeneous width of the ensemble including variations of the spatial atom-field coupling within the resonator. We present conditions on the atom numbers, the pump and coupling strengths required to reach the buildup of collective atomic coherence as well as scaling and limitations for the achievable laser line-width. We show how sufficiently large numbers of atoms subject to strong optical pumping can induce synchronisation of the atomic dipoles over a large bandwidth. This generates collective stimulated emission of light into the cavity mode leading to narrow-band laser emission at the average of the atomic frequency distribution. The line-width is orders of magnitudes smaller than that of the cavity as well as the inhomogeneous gain broadening and exhibits reduced sensitivity to cavity frequency noise [2].

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Detecting the topological phase of the Kitaev Model via network analysis

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Complex networks represent a powerful tool for analysing emerging phenomena in a wide range of fields and applications [1]. As shown in Ref. [2], they have also been shown to be able to capture the critical behaviour of collective quantum systems. In such an approach, one can construct a classical network whose links are given by the bipartite quantum correlations of the ground state of the extended systems, whose critical properties can be detected by observing the degree of complexity of such a network. In our work, we construct a classical correlation network to detect the quantum critical points of the 1D Kitaev model of finite size. The links of the network represent quantum correlations such as mutual information or the concurrence, which helps to infer the entanglement structure of the quantum system. Using network analysis, we show that this method is able to capture the topological critical value of the chemical potential and observe a peculiar point not detected by previous correlation measures. This point signals the presence of a network with clustering equal to one [3].

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Clean two-dimensional Floquet time-crystal

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The possibility of a novel, fascinating, phase of matter, dubbed time crystal, was proposed a decade ago [1]. The time-crystalline phase is characterised by the spontaneous breaking of the continuous time translational symmetry of the system. A number of no-go theorems [2], however, pose strong constraints on the possibility of such symmetry breaking. One way to elude those limitations is to resort to the so-called discrete time crystals (DTC) [3, 4], i.e. periodically driven systems that manifest a robust periodic response. In order to realise such a phase of matter the driving must avoid the heating of the system, which eventually brings to the disruption of the space-time order.
A typical setup in which this happens is given by strong disordered systems, in which many-body localisation and the presence of quasi-local conserved charges, prevent local excitations from diffusing. The search of disorder-free DTCs that display alternative mechanisms to evade thermalisation is, however, an intriguing quest.
In particular, in this work we extend the results of Ref.[5] in which the clean one-dimensional quantum Ising Model, subjected to periodic imperfect global spin flips, is studied and the possibility of a DTC phase is ruled out for the short-range interacting case. In our work, we consider the analogous two-dimensional case, and we show numerically that the system can sustain a DTC phase. Moreover we show that, in the high-frequency limit, despite an unbounded energy pumped into the system, a well defined effective Hamiltonian controls a finite-temperature intermediate regime, wherein local time-averages of the observables are described by their thermal average. As a consequence, the long-lived stability of the DTC relies on the existence of a long-range ordered phase at finite temperature.

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Dissipation in superfluid transport through an atomic quantum point contact

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We report on the effects of spin-dependent and spin-independent dissipation on the non-linear superfluid transport of a strongly interacting Fermi gas through a quantum point contact (QPC). Using shaped light we can create almost arbitrary potential landscapes for the atoms as well as effective magnetic fields and dissipation channels to alter and probe their transport. We introduce spin selective dissipation via an optical tweezer inside a QPC by tuning the laser to a weak line only addressing one of the constituents of the unitary Fermi gas, for spin-independent dissipation we address a molecular line. The dissipation has a strong effect on the transport of the superfluid changing it from nonlinear to linear. In addition the spin-dependent dissipation introduces a spin-current which allows us to study the coupling between spin and particle currents in the strongly interacting regime. These results open the way to studying the coupling of particle, heat and spin transport in an atomic quantum point contact.

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Accessing ground-state and excited-state energies in a many-body system after symmetry restoration using quantum computers

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We explore the possibility to perform symmetry restoration with the variation after projection technique on a quantum computer followed by additional post-processing. The final goal is to develop configuration interaction techniques based on many-body trial states pre-optimised on a quantum computer. We show how the projection method used for symmetry restoration can prepare optimised states that could then be employed as initial states for quantum or hybrid quantum-classical algorithms. We use the quantum phase estimation and the quantum Krylov approaches for the post-processing. The latter method combined with the quantum variation after projection leads to very fast convergence toward the ground-state energy. The possibility to access excited states energies is also discussed. Illustrations of the different techniques are made using the pairing Hamiltonian.

[1] Ruiz Guzman, E. A., & Lacroix, D. (2022). Accessing ground-state and excited-state energies in a many-body system after symmetry restoration using quantum computers. Phys. Rev. C, 105(2), 24324. https://doi.org/10.1103/PhysRevC.105.024324

Accumulative reservoir construction: A unified framework for continuous and periodic refreshing within quantum transport simulations

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The simulation of non-equilibrium many-body systems with many baths and finite temperatures is challenging. The requirement to represent infinite environments and long-time evolution to reach a steady-state makes it exceptionally difficult to study with numerical techniques.
An increasingly utilized and natural approach to control the complexity of the task is to cast the baths within an open quantum system. There are many ways to do so, ranging from continuous Lindblad relaxation to discrete refresh events. We introduce an accumulative reservoir construction that employs a series of partial renewals of the reservoir modes. Through this series, the representation accumulates the character of an infinite reservoir.
We study the range of behavior within this framework and how it impacts both accuracy and computational cost. These results provide the basis for comparing different open system methods for obtaining steady state dynamics.

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