Quantum Thermodynamics Conference 2022

Queen's University Belfast

Posters

Book of abstracts

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Session I

I-01 Jeongrak Son
Position and affiliation: Postgraduate @ Nanyang Technological University
Country: Singapore

Title: Catalysis in Action via Elementary Thermal Operations

Abstract:
Catalysts are auxiliary states that interact with the system of interest during a process, and recover their original state afterwards. The benefit of appending such an ancilla has been reported in many frameworks, including quantum thermodynamics. Nevertheless, current results focus mainly on conditions for catalytic advantage. In contrast, the dynamics of catalytic processes have remained unexplored. Moreover, the existing state transition conditions relying on initial and final states, washes out what happens in a continuous-time setting, preventing us from gleaning insight into the potential mechanisms that make a catalyst useful. Motivated by the status quo, we study catalysis in elementary thermal operations (ETO), an experimentally motivated subset of thermal operations, and show that catalysis enhances ETO, which was previously unknown. The structure of ETOs furthermore allow us to trace intermediate steps of the evolution, enabling a study on how system and catalyst explicitly interact with each other. A critical tool we develop is the strengthening of existing upper bounds of computational cost for ETOs, which leads to 1) a full characterization of the three-dimensional system transitions, and 2) computationally tractable numerics for higher dimensions. Interestingly, non-trivial catalyses with exact recovery are found even in the simplest case of a qutrit system and qubit catalyst, fostering experimental implementation together with straightforward operational recipes provided by ETO. Finally, we capture "snapshots" of the catalysis at work, by tracking local free energies of the system-catalyst during evolution. We observed that the system free energy, which always decrease after each ETO, can increase momentarily during the catalytic processes by borrowing catalyst free energies. Our work provides the first analysis of catalysis mechanism occurring in practicable setup, paving the way for a more in-depth understanding of catalytic processes.

Jeongrak Son and Nelly Ng, Catalysis in Action via Elementary Thermal Operations, (In preparation).

I-02 Stefano Cusumano
Position and affiliation: Postdoc @ International Centre for Theory of Quantum Technologies, University of Gdansk, Wita Stwosza 63, 80308 Gdansk, Poland
Country: Poland

Title: Thermodynamics of Reduced State of the Field

Abstract:
Recent years have seen the flourishing of research devoted to quantum effects on mesoscopic and macroscopic scales. In this context, in Entropy 2019, 21, 705, a formalism aiming at describing

macroscopic quantum fields, dubbed Reduced State of the Field (RSF), was envisaged. While, in the original work, a proper notion of entropy for macroscopic fields, together with their dynamical equations, was derived, here, we expand thermodynamic analysis of the RSF, discussing the notion of heat, solving dynamical equations in various regimes of interest, and showing the thermodynamic implications of these solutions.

I-03 Carolyn Wood

Position and affiliation: Postgraduate @ The University of Queensland
Country: Australia

Title: Operational models of temperature superpositions

Abstract:
When thermodynamical quantities are associated with quantum systems a question arises how to treat scenarios where the notion of temperature could exhibit some quantum features. It is known that the temperature of a gas in thermal equilibrium is not constant in a gravitational field, but it is not known how a delocalised quantum system would thermalise with such a bath. In this theoretical work we demonstrate two scenarios in which the notion of a `superposition of temperatures' arises. First: a probe interacting with different baths dependent on the state of another quantum system (control). Second: the probe interacting with a bath in a superposition of purified states, each associated with a different temperature. We show that these two scenarios are fundamentally different and can be operationally distinguished. Moreover, we show that the probe does not in general thermalise even when the involved temperatures of the baths or purifications are equal. Furthermore, we show the final probe state depends on the specific realisation of the thermalising channels, being sensitive to the particular Kraus representations of the channels. This point appears to explain recent results obtained in the context of quantum interference of relativistic particle detectors thermalising with Unruh or Hawking radiation. Finally, we show that these results are reproduced in partial and pre-thermalisation processes, and thus our approach and conclusions also generally apply beyond the idealised scenarios, where thermalisation is not exact.

Wood, C. E., Verma, H., Costa, F., & Zych, M. (2021). Operational models of temperature superpositions. arXiv preprint arXiv:2112.07860.

I-04 David Gelbwaer-Klimovsky

Position and affiliation: Faculty @ Technion
Country: Israel

Title: Violation of detailed balance in open quantum systems

Abstract:
Detailed balance at equilibrium is a core principle of today’s thermo-dynamics. It ensures the lack of persistent currents at equilibrium. It plays a key role in many fields, including the Onsager relations, reaction kinetics, fluctuation theorems, open quantum systems, and Kirchhoff’s law. Moreover, detailed balance has been so closely identified with thermal equilibrium that its violation has been used as an indicator of lack of equilibrium.

Interestingly, local detailed balance is not actually required by any thermodynamic law. This was long ago recognized by Onsager, who brought up the Hall effect as an example where these principles do not hold.
Another example in which local detailed balance does not always hold is in non-reciprocal systems. Many surprising theoretically thermal effects in non-reciprocal materials have been found in the last years: persistent heat currents in thermal equilibrium, violations of the Kirchhoff law, deviations from the Green-Kubo relations. Unfortunately, current tools are insufficient for developing the microscopic models needed to study the dynamics and thermodynamics of these systems. The weakly coupled Lindblad equation cannot be used as it requires local detailed balance. The lack of microscopic models has resulted in contradicting statements in the literature regarding basic thermodynamic properties, such as the possibility of reaching∗ thermal equilibrium and the divergence of entropy production
To clarify the thermodynamic properties of non-reciprocal systems, we develop a Lindblad master equation appropriate for these systems. To achieve this, we use the low-density limit which does not require the fulfillment of detailed balance in equilibrium. In this talk, I will present this Lindblad master equation and discuss the thermodynamic properties of systems that violate local detailed balance.

Gelbwaser-Klimovsky, D., Alicki, R.Violation of detailed balance in open quantum systems In preparation.
Gelbwaser-Klimovsky, D., Graham, N., Kardar, M., & Krüger, M. (2021). Equilibrium forces on non-reciprocal materials. In preparation.
Gelbwaser-Klimovsky, D., Graham, N., Kardar, M., & Krüger, M. (2021). Near field propulsion forces from nonreciprocal media. Physical Review Letters, 126(17), 170401.

I-05 Francesco Buscemi
Position and affiliation: Faculty @ Nagoya University
Country: Japan

Title: Thermodynamic reverse bounds for open quantum processes

Abstract:
Various quantum thermodynamic bounds are shown to stem from a single tighter and more general inequality, consequence of the operator concavity of the logarithmic function. Such an inequality, which we call the "thermodynamic reverse bound", is compactly expressed as a quantum relative entropy, from which it inherits mathematical properties and meaning. As concrete examples, we apply our bound to evaluate the thermodynamic length for open processes, the heat exchange in erasure processes, the maximal energy outflow in general quantum evolutions, and other bounds involving the entropy gain and approximate reversibility of quantum channels.

https://doi.org/10.1103/PhysRevA.102.032210

I-06 Paolo Solinas
Position and affiliation: Faculty @ University of Genova, Genova, Italy
Country: Italy

Title: Measurement of work and heat in the classical and quantum regimes

Abstract:
Despite the increasing interest in the research field which studies the concepts of work and heat at the quantum level, two important questions remain still open: can work and heat at the quantum level can manifest pure quantum features and can these quantum features be used to increase efficiency in energy manipulation? In the attempt to answer these questions, I will present an approach to measure these quantities with a quantum detector.
This approach allows us to obtain a full characterization of the dissipated heat, work, and internal energy variation in a quantum system interacting with an engineered environment. As a prototypical example, I will consider a two-level quantum system interacting with an engineered environment and its implementation on an IBMQ quantum computer. The experimental data allow us to construct quasiprobability distribution functions from which we recover the correct averages of work, heat, and internal energy variation in the dissipative processes.
As for the Wigner function, the negative regions of these quasiprobability distribution functions are the signature of pure quantum features. Interestingly, by increasing the environment coupling strength, we observe a reduction of the pure quantum features of the energy exchange processes that can be interpreted as the emergence of the classical limit. This makes the present approach a privileged tool to study, understand and exploit quantum effects in energy exchanges.

P. Solinas, M. Amico, and N. Zanghì, Phys. Rev. A 103, L060202 – 2021
P. Solinas, M. Amico, and N. Zanghì, arXiv:2110.05768

I-07 Andrea Solfanelli

Position and affiliation: Postgraduate @ SISSA Trieste
Country: Italy

Title: Quantum thermodynamic methods to purify a qubit on a quantum processing unit

Abstract:
We report on two quantum thermodynamic methods to cool down a qubit on a quantum processing unit (QPU) equipped with (nearly) identical qubits. The first method is a three qubit design that emulates the well known two qubit swap engine. Similar to standard fridges, the method allows to cool down a qubit at the expense of heating two other qubits. The second method is a three qubit design that is more practical and allows for enhanced refrigeration tasks, such as increasing the purity of one qubit at the expense of decreasing the purity of the other two. Both methods are based on the application of properly designed quantum circuits, accordingly, they can be run on any gate model quantum computer. We implement them on a publicly available superconducting qubit based QPU, and observe a cooling capability down to $52 mK$ for the first method and purification capability down to 200 mK for the second. We identify gate noise as the main obstacle towards practical application in quantum computing.

Andrea Solfanelli, Alessandro Santini, and Michele Campisi, Quantum thermodynamic method to refrigerate a qubit on a quantum processing unit (2022), arXiv:2201.13319 [quant-ph].

I-08 Olha Bahrova

Position and affiliation: Postgraduate @ [1] Center for Theoretical Physics of Complex Systems, Institute

for Basic Science, Daejeon, 34126, Republic of Korea, [2] B. Verkin Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine, 47 Nauky Ave., Kharkiv 61103, Ukraine
Country: Korea, Republic of

Title: Ground-state cooling of mechanical vibrations in a hybrid nanoelectromechanical device.

Abstract:
Nanoelectromechanical devices are in the spotlight of cutting-edge technology as well as fundamental condensed matter physics [1,2].
We consider a nanoelectromechanical system that consists of a carbon nanotube suspended above a trench in a normal metal electrode and positioned in a gap between two superconductring leads. The nanotube is treated as a movable single-level quantum dot in which the position-dependent superconducting order parameter is induced due to the superconducting proximity effect. We demonstrate that electron tunneling processes significantly affect the state of the mechanical subsystem. Using the reduced density matrix technique, we have found that the Wigner function characterizing a stationary state of the mechanical subsystem, has a Boltzmann distribution form with an effective temperature that can reach remarkable low values [3]. The emergence of this effect crucially depends on the direction of the bias voltage applied to the normal lead, and the relative position of the quantum dot level. We also show that the nanotube fluctuations strongly affect the dc current through the system, a characteristic that can be used for direct experimental observation of the predicted phenomenon.

[1] A.N. Cleland, Foundation of Nanomechanics, Springer, New York, 2002.
[2] J.P. Pekola and B. Karimi, Rev. Mod. Phys. 93, 041001 (2021).
[3] O.M. Bahrova, S.I. Kulinich, L.Y. Gorelik, R.I. Shekhter, H.C. Park, arXiv: 2202.08009 (2022).

I-09 Onur Pusuluk
Position and affiliation: Postdoc @ Koç University
Country: Turkey

Title: Thermocoherent effect: Generalization of Onsager's reciprocity relations for heat and quantum correlations

Abstract:
Although thermoelectric effects were experimentally discovered by (Seebeck and Peltier) between 1821–34, the underlying theory remained immature until Lars Onsager published his famous reciprocal relations between heat and charge in 1931 [1]. Onsager's paper was built on a paper of Lord Rayleigh [2], in which he focused for the first time on the whole dynamical process by which a thermodynamic steady state is attained. He captured the essential physics by developing a simplified collision model, which in turn allowed him to reveal the role of the environment's initial conditions in heat conduction.
In this talk, we will follow Lord Rayleigh and Lars Onsager's footsteps to systematically establish quantum reciprocal relations between heat and quantum coherence and correlations, for which we introduce the term "thermocoherent effect" [3]. We'll explore Rayleigh's dynamical problem to equilibration in the quantum regime. For arbitrary collision times and initial states, we'll develop the quantum master and Fokker-Planck equations. By identifying the quantum version of Rayleigh's heat conduction equation, we'll show that quantum discord and entanglement can contribute to genuine heat flow only when they

are associated with so-called heat-exchange coherences. Analogous to Onsager's use of Rayleigh's principle of least dissipation of energy, we'll use the entropy production rate to identify the coherence current. We'll write both coherence and heat flows in the form of quantum Onsager relations, from which we predict coherent Peltier and coherent Seebeck effects. Finally, we'll discuss some of the possible experimental realizations and technological applications of the thermocoherent phenomena in different platforms.

[1] L. Onsager, Reciprocal relations in irreversible processes. I., Phys. Rev. 37, 405 (1931).
[2] J. W. Strutt (3rd Baron Rayleigh), Dynamical problems in illustration of the theory of gases. Lond. Edinb. Dubl. Philos. Mag. 32, 424 (1891).
[3] O. Pusuluk and Ö.E. Müstecaplıoğlu, Quantum Rayleigh problem and thermocoherent Onsager relations. Phys. Rev. Research 3, 023235 (2021).

I-10 Mohamed Farouk Ghiti
Position and affiliation: Faculty @ 1/Ecole Normale Supérieure, ENSC, Assia Djebar, Constantine, Algeria. 2/ Laboratoire de Physique Mathématique et Subatomique, LPMS, Université des Frères Mentouri, Constantine, Algeria
Country: Algeria

Title: The Quantum Thermodynamics of Entangled Massless Scalar Particles in the Noncommutative Anisotropic Bianchi I spacetime

Abstract:
Using the Von Neumann entropy, we evaluate the created quantum entanglement of massless bosonic particles in noncommutative (NC) Bianchi I spacetime. Using this entropy, one can recover some thermodynamical properties, like chemical potential, in NC Bianchi I spacetime. Due to the non-commutativity θ parameter, one can show that the created boson-antiboson pair forms a Bose-Einstein condensate (BEC) which affects the behavior of the quantum entanglement.

[1] S. Hill, W. K. Wootters, Phys. Rev. Lett 78, 5022 (1997).
[2] V. Vedral, M. B. Plenio, M. A. Rippin and P. L. Knight, Phys. Rev. Lett 78, 2275 (1997).
[3] M. F. Ghiti, N. Mebarki and H. Aissaoui, Int. J. Modern. Phys. A 30, 1550141 (2015).
[4] I. Fuentes, R. B. Mann, E. M. Martinez and S. Moradi, Phys. Rev. D 82, 045030 (2010).
[5] N. Mebarki, L. Khodja and S. Zaim, Electron. J. Theor. Phys. 7, 181 (2010).
[6] N. Mebarki, S. Zaim, L. Khodja and H. Aissaoui, Phys. Scrip. 78, 045101 (2008).
[7] V. M. Villalba and W. Greiner, Phys. Rev. D 65, 025007, (2001).

I-11 Fadwa Benabdallah
Position and affiliation: Undergraduate @ LPHE-Modeling and Simulation, Faculty of Sciences, Mohammed V University in Rabat, Morocco
Country: Morocco

Title: Dynamics of negativity and geometric quantum discord in a qubit-qutrit spin system under the effect of dephasing noise

Abstract:
We study the dimensionless time evolution of the logarithmic negativity and geometric quantum discord of a qubit-qutrit XXX spin model under both Markovian and non-Markovian noise channels. We find that at a special temperature interval the quantum entanglement based on the logarithmic negativity reveals entanglement sudden deaths together with revivals. The revival phenomenon is due to the non-Markovianity resulting from the feedback effect of the environment. At high temperatures, the scenario of death and revival disappears. The geometric quantum discord evolves alternatively versus time elapsing with damped amplitudes until the system reaches a steady state. It is demonstrated that the dynamics of entanglement negativity undergo substantial changes by varying temperature, and it is much more fragile against the temperature rather than the geometric quantum discord.

F. Benabdallah, H. Arian Zad, M. Daoud and N. Ananikian, "Dynamics of quantum correlations in a qubit-qutrit spin system under random telegraph noise", Phys. Scr. 96 125116 (2021).

I-12 Alexander Teretenkov
Position and affiliation: Postdoc @ Steklov Mathematical Institute of Russian Academy of Sciences
Country: Russian Federation

Title: Generalized Effective Quantum Thermodynamics

Abstract:
Based on the similarity between effective Gibbs state for averaged observables and mean force Gibbs states, we discuss the possibility of introducing a generalized effective thermodynamics for an arbitrary projector. In the equilibrium case, by projector, we mean the projector that appears in the Nakajima-Zwanzig approach to the derivation of master equations. In the non-equilibrium case, we consider some of its generalizations as well.

I-13 Alessandro Candeloro
Position and affiliation: Postgraduate @ University of Milan
Country: Italy

Title: Energetics of bipartite interacting quantum system and the quantum heat

Abstract:
The field of quantum thermodynamics aims to extend the laws of standard thermodynamics to non-equilibrium phenomena, especially in systems outside the thermodynamic limit and including inherent quantum effects. Usually, work is defined in terms of a time-dependent Hamiltonian, while heat is the energy exchanged with a bath, a non-accessible external system [1]. Following this approach, the energetic footprint is determined by the nature of the external system providing the energy. On the other hand, the formalism of quantum mechanics allows us to describe an interacting and isolated quantum system. For a bipartite system, quantum energetics can be studied by decomposing the density matrix in a local component and one encoding the correlations [2,3,4,5]. In this framework, an energy change coming from a local unitary effective drive is considered work; conversely, the energy exchanged from the non-unitary component of the evolution, due to the build-up of correlations, yields heat. We show how these quantities satisfy balance equations which also account for the change in the coupling

energy. Furthermore, our approach is valid even in the strong coupling regime and in the cases where the coupling energy is not negligible [6]. Finally, we apply this framework to a pre-measurement process, which can be modeled as a unitary interaction between the measured system *S* and a meter *M*. For a conservative measurement during which the energy of the meter is constant, we show that the total heat flow exchanged during the unitary pre-measurement process coincides with the quantum heat, the irreversible change of the energy of a measured system [7,8]. Eventually, we propose a paradigmatic example, i.e. a qubit measured by a single mode in a cavity. Our results provide tools to analyze the energetics of quantum systems at a purely quantum level, where the work and heat sources can be purely modeled as quantum systems.

[1] Felix Binder, Luis A. Correa, Christian Gogolin, Janet Anders, and Gerardo Adesso, Thermodynamics in the quantum regime: fundamental aspects and new directions (Springer, 2019).
[2] Hendrik Weimer, Markus J. Henrich, Florian Rempp, Heiko Schröder, and Günter Mahler, Local effective dynamics of quantum systems: A generalized approach to work and heat Europhysics Letter, 83, 30008 (2008).
[3] Hoda Hossein-Nejad, Edward J. O'Reilly, and Alexandra Olaya-Castro, Work, heat and entropy production in bipartite quantum systems, New Journal of Physics 17, 075014 (2015).
[4] Alipour, S., F. Benatti, F. Bakhshinezhad, M. Afsary, S. Marcantoni, e A. T. Rezakhani. « Correlations in Quantum Thermodynamics: Heat, Work, and Entropy Production». Scientific Reports 6, (2016): 35568.
[5] Maffei, Maria, Patrice A. Camati, e Alexia Auffèves. «Probing Nonclassical Light Fields with Energetic Witnesses in Waveguide Quantum Electrodynamics». Physical Review Research 3, n. 3 (2021): L032073.
[6] Alessandro Candeloro, Patrice A. Camati, Léa Bresque, and Alexia Auffèves, (in preparation).
[7] Elouard, Cyril, David A. Herrera-Martí, Maxime Clusel, e Alexia Auffèves. «The Role of Quantum Measurement in Stochastic Thermodynamics». Npj Quantum Information 3, (2017): 9.
[8] Jordan, Andrew N., Cyril Elouard, e Alexia Auffèves. «Quantum Measurement Engines and Their Relevance for Quantum Interpretations». Quantum Studies: Mathematics and Foundations 7, (2020): 203–15.

I-14 Marcin Łobejko

Position and affiliation: Postdoc @ International Centre for Theory of Quantum Technologies, University of Gdansk
Country: Poland

Title: Towards reconciliation of completely positive open system dynamics with equilibration postulate

Abstract:
Almost every quantum system interacts with a large environment, so the exact quantum mechanical description of its evolution is impossible. One has to resort to approximate description, usually in the form of a master equation. There are at least two basic requirements for such description: first of all, it should preserve positivity of probabilities; second, it should reproduce the wisdom coming from thermodynamics - systems coupled to a single thermal bath tend to the equilibrium, which is the marginal state of the composite Gibbs state. Existing two widespread descriptions of evolution fail to satisfy at least one of those conditions. The so-called Davies master equation, while preserving positivity of probabilities (due to Gorini-Kossakowski-Sudarshan-Lindblad form), fails to describe thermalization properly. On the other hand, the Bloch-Redfield master equation violates the positivity of probabilities, but it properly describes equilibration at least for off-diagonal elements for several important scenarios. However, is it possible to have a description of open system dynamics that would share both features? In

this paper, we partially resolve this problem: (i) We provide general form, up to second order, of the proper thermal equilibrium state (called in literature the mean-force state) for an arbitrary open system. (ii) We show that the off-diagonal part of the mean-force is a steady-state solution for the Bloch-Redfield equation. (iii) We consider a so-called cumulant equation (called also refined weak coupling limit), which is explicitly completely positive, and we show that up to second order, its steady-state coherences are the same as one of the Bloch-Redfield dynamics.

I-15 Anton Trushechkin
Position and affiliation: Faculty @ Steklov Mathematical Institute of Russian Academy of Sciences
Country: Russian Federation

Title: Quantum master equations and thermodynamics in the ultrastrong-coupling limit and the strong-decoherence limit

Abstract:
In the framework of theory of open quantum systems, we derive quantum master equations for the ultrastrong system-bath coupling regime and, more generally, the strong-decoherence regime. In this regime, the strong decoherence is complemented by slow relaxation processes. We use a generalization of the Forster and modified Redfield perturbation theories known in theory of excitation energy transfer. Also, we show that the mean-force Gibbs state [1] in the corresponding limits is stationary for the derived master equations. We show that the steady state corresponds to the so-called mean-force Gibbs state, which confirms the conjecture of Ref. [2]. This part of the talk is based on the preprint [3]. As a continuation, we develop thermodynamics for this regime, which generalizes the thermodynamics of pure decoherence [4,5].

[1] A. S. Trushechkin, M. Merkli, J. D. Cresser, and J. Anders, Open quantum system dynamics and the mean force Gibbs state, arXiv:2110.01671, to appear in AVP Quantum Science
[2] J. D. Cresser and J. Anders, Weak and ultrastrong coupling limits of the quantum mean force Gibbs state, Phys. Rev. Lett. 127, 250601 (2021).
[3] A. Trushechkin, Quantum master equations and steady states for the ultrastrong-coupling limit and the strong-decoherence limit, arXiv:2109.01888
[4] M. Popovic, M. T. Mitchison, and J. Goold, Thermodynamics of decoherence, arXiv:2107.14216.
[5] G. Francica, Work done in a decoherence process, arXiv:2109.09135.

I-16 Dario Poletti
Position and affiliation: Faculty @ Singapore University of Technology and Design
Country: Singapore

Title: Typicality of nonequilibrium (quasi-)steady currents

Abstract:
The understanding of the emergence of equilibrium statistical mechanics has progressed significantly thanks to developments from typicality, canonical and dynamical, and from the eigenstate thermalization hypothesis. Here we focus on a nonequilibrium scenario in which two nonintegrable systems prepared in different states are locally and non-extensively coupled to each other. Using both

perturbative analysis and numerical exact simulations of up to 28 spin systems, we demonstrate the typical emergence of nonequilibrium (quasi-)steady current for weak coupling between the subsystems. We also identify that these currents originate from a prethermalization mechanism, which is the weak and local breaking of the conservation of the energy for each subsystem.

https://arxiv.org/abs/2111.13019

I-17 Francesco Albarelli

Position and affiliation: Postdoc @ Università degli Studi di Milano
Country: Italy

Title: Probe incompatibility in multiparameter noisy quantum metrology

Abstract:
We derive fundamental bounds on the maximal achievable precision in multiparameter noisy quantum metrology, valid under the most general entanglement-assisted adaptive strategy, which are tighter than the bounds obtained by a direct use of single-parameter results.
This allows us to study the issue of the optimal probe incompatibility in the simultaneous estimation of multiple parameters in generic noisy channels, while so far the issue has been studied mostly in effectively noiseless scenarios (where the Heisenberg scaling is possible).
We apply our results to the estimation of both unitary and noise parameters, and indicate models where the fundamental probe incompatibility is present.
In particular, we show that in lossy multiple arm interferometry the probe incompatibility is as strong as in the noiseless scenario, reducing the potential advantage of simultaneous estimation to a constant factor.
Finally, going beyond the multiparameter estimation paradigm, we introduce the concept of *random quantum sensing* and show how the tools developed may be applied to multiple channel discrimination problems.
As an illustration, we provide a simple proof of the loss of the quadratic advantage of time-continuous Grover algorithm in presence of dephasing or erasure noise.

Phys. Rev. X, in press, 2022, http://arxiv.org/abs/2104.11264

I-18 Harshit Verma

Position and affiliation: Postgraduate @ University of Queensland
Country: Australia

Title: Estimating two temperatures using quantum processes, and Mach-Zehnder interferometer

Abstract:
Quantum control over the order of application of quantum channels – in a setup called quantum switch [1] – has been proposed to be advantageous in various thermodynamical and communication tasks [2]. The switch belongs to a broader class of constructs called quantum processes, which are essentially higher-order linear transformations from quantum maps to quantum maps. Here we consider quantum processes and Mach-Zehnder interferometer (MZI) with two quantum channels thermalizing to distinct

temperatures for the task of thermometry. Notably, the scheme with MZI has been proposed as a setup for operational models of temperature superposition [3]. We show that different types of quantum processes and MZI are suitable for such a two-temperature estimation task. We provide the bounds on variances of the temperatures, obtained through multi-parameter Cramer-Rao bounds [4], and show that these bounds are, in general, attainable. Our numerical results demonstrate that there is no significant advantage offered by quantum processes, and MZI for the two-temperature estimation task if compared with the case wherein the temperatures are estimated using independent probes.

[1] Goswami, K., Giarmatzi, C., Kewming, M., Costa, F., Branciard, C., Romero, J., & White, A. G. (2018). Indefinite Causal Order in a Quantum Switch. Phys. Rev. Lett., 121(9), 90503. https://doi.org/10.1103/PhysRevLett.121.090503
[2] Ebler, D., Salek, S., & Chiribella, G. (2018). Enhanced Communication with the Assistance of Indefinite Causal Order. Phys. Rev. Lett., 120(12), 120502. https://doi.org/10.1103/PhysRevLett.120.120502
[3] Wood, C. E., Verma, H., Costa, F., & Zych, M. (2021). Operational models of temperature superpositions. http://arxiv.org/abs/2112.07860
[4] Liu, J., Yuan, H., Lu, X.-M., & Wang, X. (2019). Quantum Fisher information matrix and multiparameter estimation. Journal of Physics A: Mathematical and Theoretical, 53(2), 23001. https://doi.org/10.1088/1751-8121/ab5d4d

I-19 Hector Silva
Position and affiliation: Postgraduate @ Universitat Autonoma de Barcelona
Country: Spain

Title: Dynamics of Open Quantum Systems Exchanging Energy and Particles with Finite Baths

Abstract:
In this work we derive a master equation for a system in contact with one or multiple baths, whose energy and particle number can change during the process. Using observational entropy as the standard entropy for open quantum systems we show that the laws of thermodynamics still hold for this system. We apply this master equation to understand recent transport experiments with ultra-cold atoms, where we are able to provide a consistent thermodynamic interpretation without using the local equilibrium assumption.

I-20 Kacper Prech
Position and affiliation: Postgraduate @ University of Basel
Country: Switzerland

Title: Entanglement and TUR violations - two manifestations of quantum coherence

Abstract:
Entanglement, a form of correlation that is stronger than what classical systems are capable of, is a prominent manifestation of quantum coherence. Recently, a different manifestation of coherence has been discovered: systems exhibiting quantum coherence have been found to violate inequalities that bound the signal-to-noise ratio of any current in classical systems, so-called thermodynamic uncertainty relations (TUR). We systematically analyze the relation between these two different manifestations of coherence in a serial double quantum dot.

In this system, entanglement can be generated by driving a charge current through the double dot [1]. That same current may exhibit a suppression of fluctuations due to quantum coherence, allowing for TUR violations [2]. We find that TUR violations and entanglement are present for the same range of tunnel-couplings. However, while TUR violations require small bias voltages (keeping dissipation small), entanglement is maximized in the large bias limit. Increasing the bias voltage, we observe a cross-over from TUR violations to entanglement with the window of co-existence for intermediate voltages. We include Coulomb interaction and the spin degree of freedom in our calculations, as these are often unavoidable ingredients in an experimental setup. For large inter-dot Coulomb interaction and in the large bias limit, we find an amount of entanglement that exceeds the results of previous studies.

[1] Brask J B, Haack G, Brunner N and Huber M 2015 New Journal of Physics 17 113029, https://doi.org/10.1088/1367-2630/17/11/113029
[2] Ptaszynski K 2018 Phys. Rev. B 98(8) 085425, https://doi.org/10.1103/PhysRevB.98.085425

I-21 Salvatore Tirone

Position and affiliation: Postgraduate @ Scuola Normale Superiore di Pisa
Country: Italy

Title: Noisy quantum batteries: optimizing the output ergotropy

Abstract:
Energy-storing devices which use quantum effects (quantum batteries) are expected to provide an advantage in terms of charging power with respect to their classical counterparts[1]. However another crucial feature that needs to be assessed is the ability of quantum batteries to store energy through a period of time withstanding self-discharging and noise.
In this work we characterize the best way to store a total energy E in an array of n (two-level) noisy quantum batteries, with the aim of retrieving the maximum possible energy after the batteries have undergone some environmental noise. We consider several kinds of detrimental noise: energy decay and thermalization (generalized amplitude damping channels)[2,3,4], loss of coherence (dephasing channels)[2,3] and depolarization[2,3].
We consider both the case in which the allowed number of quantum batteries n is restrained to a fixed fraction of the initial energy E to store in the batteries, and the case in which we are allowed to use an unlimited number of quantum batteries ($E/n \rightarrow 0$). For some noise channels (most notably, the generalized amplitude damping channel) storing the energy in a large number of batteries is the best way to prevent the degradation of extractable work due to the use of quantum coherence in energy allocation. However, this is not the case for all the kinds of models: we find some quantum channels for which the ergotropy[5] is best preserved by keeping a finite ratio $\ell = E/n$.. This result shows that quantum resources, apart from providing an advantage in the charging power of quantum batteries, can also be helpful in preventing their degradation by environmental noise.

[1] D. Rossini, G. M. Andolina, D. Rosa, M. Carrega, and M. Polini, Quantum Advantage in the Charging Process of Sachdev-Ye-Kitaev Batteries, Phys. Rev. Lett. 125, 236402 (2020).
[2] M. A. Nielsen and I. L. Chuang, Quantum Computation and Quantum Information: 10th Anniversary Edition (Cambridge University Press, Cambridge, England, 2010).
[3] M. M. Wilde, Quantum Information Theory (Cambridge University Press, Cambridge, England, 2013).
[4] S. Khatri, K. Sharma, and M. M. Wilde, Information-theoretic aspects of the generalized amplitude-damping channel, Phys. Rev. A 102, 012401 (2020).

[5] A. E. Allahverdyan, R. Balian, and Th. M. Nieuwenhuizen, Maximal work extraction from finite quantum systems, Europhys. Lett. 67, 565 (2004).

I-22 Marcelo Janovitch Broinizi Pereira

Position and affiliation: Postgraduate @ University of Basel
Country: Switzerland

Title: Breakdown of wave-particle duality in the classical limit of a quantum heat engine

Abstract:
Quantum heat engines have spurred a lot of interest in the recent years, and, although their classical counterparts have been thoroughly investigated in the last centuries, the quantum-to-classical transition remains elusive. In this ongoing investigation, we consider a quantum heat engine based on photon-assisted Cooper pair tunnelling. Its quantum description exhibits a dual wave-particle behaviour, but a comparison with viable classical models has been lacking. Here, we derive different classical limits: (i) A particle model, where photons hop between two neighbouring resonators; (ii) a wave model, in which electromagnetic waves interfere. We contrast these with the quantum model at the level of current fluctuations, where non-classical features usually emerge.

DOI: 10.1103/PhysRevB.93.041418
arXiv: 2102.01395

I-23 Michal Kolář

Position and affiliation: Postdoc @ Palacký University Olomouc
Country: Czechia

Title: Measurement-Induced Manipulation of Quantum Coherence

Abstract:
The poster provides an outline of our work on manipulations of different forms of coherence [1] by diagonal (in the basis of incoherent states) quantum measurements. In [2] we have proposed a measurement-based protocol for (energy-basis) coherence synthesis from individual systems into an increased global coherence of the compound system. The building block of our system is a pair of independent and non-interacting copies of two-level system (TLS) in an initial state with low excited state population and low initial coherence. A universal option to achieve effective protocol is the usage of global projector diagonal in the energy basis. Generalization to a certain class of diagonal POVM allows for protocol optimization, e.g. for the output state coherence. The results reveal that unconstrained optimization results in local filters and the optimized coherence appears locally on each TLS. Our work [3] answers the question whether such local filters are optimal as well, if constrained optimization is considered. The answer is negative, as for given protocol success probability the optimal filters are non-local. These results are verified in a proof-of-principle linear-optical experiment. The pairwise diagonal projector used in [2] proves its universality in a more general settings. Generalized protocol [4] uses input of N non-interacting copies of TLS with low initial energy and coherence. Sequential application of the projector synthesizes input states into output with higher coherence increasing with N. We study different quantity called mutual coherence [4] as well. It captures coherence of the compound system not present locally in marginal states of subsystems. Being a new

quantity, we again study properties of mutual coherence on a paradigmatic example of a pair of TLS. We characterize the states optimizing mutual coherence in this Hilbert space. We specify and experimentally realize [5] filters transforming certain input states into these optimal states.

[1] T. Baumgratz, M. Cramer, and M. B. Plenio, Phys. Rev. Lett. 113, 140401 (2014).
[2] M. Gumberidze, M. Kolář, and R. Filip, Scientific Reports 9, 19628 (2019).
[3] R. Stárek, M. Mičuda, M. Kolář, R. Filip, and J. Fiurášek, Quantum Sci. Technol. 6, 045010 (2021).
[4] M. Gumberidze, M. Kolář, and R. Filip, Phys. Rev. A, 105, 012401 (2022).
[5] N. Horová, R. Stárek, M. Mičuda, J. Fiurášek, M. Kolář, and R. Filip, in preparation.

I-24 Mir Alimuddin
Position and affiliation: Postdoc @ Research Associate - I, School of Physics, IISER Thiruvananthapuram, Vithura, Kerala - 695551, India.
Country: India

Title: Bound on ergotropic gap for bipartite separable states

Abstract:
The presence of correlations among constituent quantum systems has great relevance in thermodynamics. Significant efforts have been devoted to investigate the role of correlations in work extraction, among others. Here we derive a bound on the difference between global and local extractable work by unitary operations (ergotropic gap) for bipartite separable states. Violation of this bound necessarily certifies the presence of entanglement. This gap is shown to be a monotone under local operations and classical communication-assisted state transformations for pure bipartite quantum states. Further, we provide a thermo-majorization criterion that is sufficient to compare the single-shot work deficit between two pure bipartite entangled states. The ergotropic gap has an implication in witnessing the dimension of a bipartite quantum state with the same local dimensions. On the other hand, our result gives an operational meaning to the Nielsen-Kempe disorder criterion. We also propose a schematic model to visualize the separability bound and to detect entanglement for a restricted class of quantum states.

https://doi.org/10.1103/PhysRevA.99.052320

I-25 Parvinder Solanki
Position and affiliation: Postgraduate @ Indian Institute of Technology Bombay
Country: India

Title: Role of Coherence and Degeneracies in Quantum Synchronisation

Abstract:
Progress on the study of synchronisation in quantum systems has been largely driven by specific examples which resulted in several examples of frequency entrainment as well as mutual synchronisation. Here we study quantum synchronisation by utilising Liouville space perturbation theory. We begin by clarifying the role of centers, symmetries and oscillating coherences in the context of quantum synchronisation. We then analyse the eigenspectrum of the Liouville superoperator generating the dynamics of the quantum system and determine the conditions under which synchronisation arises.

We apply our framework to derive a powerful relationship between energy conservation, degeneracies and synchronisation in quantum systems. Finally, we demonstrate our approach by analysing two mutually coupled thermal machines and the close relationship between synchronisation and thermodynamic quantities.

Solanki, P., Jaseem, N., Hajdušek, M., & Vinjanampathy, S. (2021). Role of Coherence and Degeneracies in Quantum Synchronisation. arXiv preprint arXiv:2104.04383.

I-26 Miku Ishizaki
Position and affiliation: Postgraduate @ the University of Tokyo
Country: Japan

Title: Switching the function of the quantum Otto cycle in non-Markovian dynamics: heat engine, heater and heat pump

Abstract:
Quantum thermodynamics explores novel thermodynamic phenomena that emerge when interactions between macroscopic systems and microscopic quantum ones go into action. Among various issues, quantum heat engines, in particular, have attracted much attention as a critical step in theoretical formulation of quantum thermodynamics and in investigation of efficient use of heat by means of quantum resources [1].
In the present research, we focus on heat absorption and emission processes as well as work extraction processes of a quantum Otto cycle [2].
We describe the former as non-Markovian dynamics [3], and thereby find that the interaction energy between a macroscopic heat bath and a microscopic qubit is not negligible. In particular, we reveal that the interaction energy is divided into the system and the bath in the short interaction time and remains negative in the long time. We quantify these two effects by defining an index of non-Markovianity in terms of the energy division of the interaction energy. Thanks to this behavior of the interaction energy, our non-Markovian quantum Otto cycle switch functions, such as an engine as well as a heater or heat pump, by controlling the interaction time with the heat bath. In addition, the qubit itself loses its energy if we shorten the interaction time; in other words, the qubit is cooled through the cycle [3]. This property produces a possibility of being utilized for cooling qubits in quantum computing.
We also describe the work extraction from the microscopic system to a macroscopic system like us humans as an indirect measurement process by introducing a work storage as a new reservoir [4].

[1] Sai Vinjanampathy, Janet Anders, Contemporary Physics 57, 4, 545 (2016)
[2] Miku Ishizaki, Hiroyasu Tajima, Naomichi Hatano, in preparation.
[3] Yuji Shirai, Kazunari Hashimoto, Ryuta Tezuka, Chikako Uchiyama, Naomichi Hatano, Phys. Rev. Research 3, 023078, (2021)
[4] Masahito Hayashi, Hiroyasu Tajima, Phys. Rev. A 95, 032132 (2017)

I-27 Md Qutubuddin
Position and affiliation: Postgraduate @ East China Normal University, Shanghai, China
Country: India

Title: photon induced optical measurements in open quantum systems: quantum heat engine perspective

Abstract:
We present a consistent optimization procedure for the optical measurements in open quantum systems using recently developed incoherent control protocol. Assigning an effective hot bath for the two-entangled-photon pump we recast the transmission of classical probe as a work in a quantum heat engine framework. We demonstrate that maximum work in such a heat engine can exceed that for the classical two-photon and one-photon pumps, while efficiency at maximum power can be attributed to conventional boundaries obtained for three-level quantum heat engine. Our results pave the way for incoherent control and optimization of optical measurements in open quantum systems that involve two-photon processes with quantum light.

I-28 Raffaele Salvia
Position and affiliation: Postgraduate @ Scuola Normale Superiore, Pisa, Italy
Country: Italy

Title: Optimal local work extraction from bipartite quantum systems in the presence of Hamiltonian couplings

Abstract:
We investigate the problem of finding the local analogue of the ergotropy, that is the maximum work that can be extracted from a system if we can only apply local unitary transformation acting on a given subsystem. This is a model for extracting work from a quantum system coupled with an environment. Previous work on the problem on local work extraction has been focused on determining the maximum energy which can be obtained with any local CPTP map (Frey et al. 2014, Alhambra et al. 2019), and on finding the local analogue of the non-equilibrium free energy (Mukherjee et al., 2016).
Differently from the problems mentioned above, the local ergotropy

$$\mathcal{E}_S(\rho_{SE}, H_{SE}) := \max_{\hat{U}_S \in \mathbf{U}(d_S)} \mathrm{Tr}[H_{SE}(\rho_{SE} - (\hat{U}_S \otimes \hat{I}_E)\rho_{SE}(\hat{U}_S^\dagger \otimes \hat{I}_E))]$$

cannot be written as the solution of a Semidefinite Program Optimization (in fact, it can be seen as a quantum generalization of the assignment problem, hence we know that no closed formula may exist for its solution the general case).
Our study is, to our knowledge, the first analysis of the problem of local ergotropy in the case in which the system and the environment are coupled by a non-trivial interaction V_{SE}. Our main result is an exact closed formula for the local ergotropy in the special case in which the local system has only two levels. We also provide upper and lower bound for the general case.
As non-trivial examples of application, we compute the local ergotropy for an atom interacting with an electromagnetic cavity with Jaynes-Cummings coupling, and the local ergotropy for a spin site in an XXZ Heisenberg chain. In both systems, we find regimes in which the local ergotropy is bigger than the ergotropy of the decoupled local system. This indicates that the environment may be a resource, and not only a nuisance, for work extraction.

R. Salvia and V. Giovannetti, Optimal local work extraction from bipartite quantum systems in the presence of Hamiltonian couplings, arXiv: 22XX.XXXX
M. Frey et al., Strong local passivity in finite quantum systems, PRE 90, 012127 (2014)
A. Alhambra et al., Fundamental Limitations to Local Energy Extraction in Quantum Systems, PRL 123, 190601 (2019)

I-29 Ramandeep Johal
Position and affiliation: Faculty @ Indian Institute of Science Education and Research Mohali
Country: India

Title: Majorization and quantum thermal machines

Abstract:
Majorization is a mathematical concept from matrix analysis [1] and a powerful technique for comparing two probability distributions or two density matrices. Measures such as entropy are essentially weaker than the notion of majorization, and do not give as much detailed information. In the context of thermodynamics, a generalized notion of majorization plays a crucial role in characterizing a necessary and sufficient condition for state conversion by thermodynamically feasible transformations--described by Gibbs preserving maps at finite temperature. Thermo-majorization give a stricter criterion than free energy difference for state transformation in small scale and highly correlated quantum systems [2]. The motive of this talk is to characterize the operation of a quantum thermal machine through majorization. We study a model of a quantum working substance with a spin-1/2 particle and an arbitrary spin-s coupled to each other by Heisenberg exchange interaction, and subject to an external magnetic field [3]. The working substance undergoes a quantum Otto cycle where the two adiabatic processes involve a change in the external magnetic field at a fixed value of the coupling constant and spaced between two isochoric processes. The model was studied in Ref. [4] based on the notion of heuristics whereby a worst-case scenario was analysed to compare between two equilibrium distributions at hot and cold reservoirs, leading to positive work condition for the engine. Here, we analyse the performance of the machine using the notion of majorization. In this manner, we obtain a simpler proof of the upper bound of efficiency [4], given by $\hat{\eta} = \eta_0(1 - 2(2s+1)J/B_1)^{-1}$, where $\eta_0 = 1 - B_2/B_1$ is the efficiency of the uncoupled system, with $B_1 > B_2$ as the higher and lower values of the external field and J as the coupling constant. We also analyse the local thermodynamics of spins.

1. Marshall A. W., Olkin I., Arnold B. C. (2011): Inequalities: Theory of Majorization and Its Applications. Springer.
2. Horodecki M., Oppenheim J. (2013) Fundamental limitations for quantum and nano thermodynamics. Nat Commun 4, 2059.
3. Altintas F., Müstecaplıoğlu Ö. E. (2015) General formalism of local thermodynamics with an example: Quantum Otto engine with a spin-1/2 coupled to an arbitrary spin. Physical Review E 92, 022142
4. Johal R. S., Mehta V. (2021) Quantum heat engines with complex working media, complete Otto cycles and heuristics. Entropy 23, 1149.
5. Sagawa T. (2020), Entropy, Divergence, and Majorization in Classical and Quantum Thermodynamics. arXiv:2007.09974
6. Gour G., Jennings D., Buscemi F., Duan R., Marvian I. (2018): Quantum majorization and a complete set of entropic conditions for quantum thermodynamics. Nat Commun 9, 5352

I-30 Samyak Pratyush Prasad
Position and affiliation: Postgraduate @ Institut Néel, Université Grenoble Alpes
Country: France

Title: Quantum energetics: connecting an open- and a closed-system approach

Abstract:
Establishing general and consistent notions of work and heat for quantum systems is one of the fundamental goals of quantum thermodynamics. A standard energetic description applies to open systems driven by a classical source, and coupled to a bath: the system exchanges work with the classical drive, and dissipates heat into the bath. We compare this open-system perspective to an alternative, closed-system one, whose notions of work and correlation energy (heat-like energy change) rely on the dynamical structure of each subsystem comprising an isolated bipartite system and the correlations present between them [1,2]. In such an approach, the solution of the full dynamics is required for evaluating the energetic quantities. We consider a two-level atom (qubit) coupled to a one-dimensional waveguide injected with a coherent field as a test-bed system to compare these two energetic perspectives. This system has been experimentally implemented in several state-of-the-art platforms: integrated photonics [3], superconducting circuits [4], and atomic physics [5]. Furthermore, the closed-system perspective has been already applied to this physical setup, leading to an experimentally accessible notion of work [6,7]. We show that the two notions of work, and correspondingly heat and correlation energy, are the same only in the classical limit where the field intensity goes to infinity. Furthermore, we pinpoint the physical quantity responsible for such a disparity. We demonstrate that the dissipator of the qubit master equation contains a Hermitian component that the closed-system perspective takes as an additional driving on the qubit. This driving is exerted by the field that the qubit itself emits in the waveguide, and hence is proportional to the coherence of its state. For this reason, this self-driving, and the associated energy change, the self-work, remain even in the absence of an input field, enabling one to define work exchanges during spontaneous emission.

[1] Hendrik Weimer, Markus J Henrich, Florian Rempp, Heiko Schröder, and Günter Mahler. Local effective dynamics of quantum systems: A generalized approach to work and heat. EPL (Europhysics Letters), 83(3):30008, 2008.
[2] Hoda Hossein-Nejad, Edward J O'Reilly, and Alexandra Olaya-Castro. Work, heat and entropy production in bipartite quantum systems. New Journal of Physics, 17(7):075014, 2015.
[3] JC Loredo, Carlos Antón, Bogdan Reznychenko, P Hilaire, A Harouri, C Millet, H Ollivier, N Somaschi, L De Santis, A Lemaître, et al. Generation of non-classical light in a photon-number superposition. Nature Photonics, 13(11):803, 2019.
[4] Xiu Gu, Anton Frisk Kockum, Adam Miranowicz, Yu-xi Liu, and Franco Nori. Microwave photonics with superconducting quantum circuits. Physics Reports, 718(1):1, 2017.
[5] Syed Abdullah Aljunid, Gleb Maslennikov, Yimin Wang, Hoang Lan Dao, Valerio Scarani, and Christian Kurtsiefer. Excitation of a single atom with exponentially rising light pulses. Phys. Rev. Lett., 111:103001, Sep 2013.
[6] Juliette Monsel, Marco Fellous-Asiani, Benjamin Huard, and Alexia Auffèves. The energetic cost of work extraction. Physical review letters, 124(13):130601, 2020.
[7] Maria Maffei, Patrice A. Camati, and Alexia Auffèves. Probing nonclassical light fields with energetic witnesses in waveguide quantum electrodynamics. Phys. Rev. Research, 3:L032073, Sep 2021.

I-31 Srijon Ghosh

Position and affiliation: Postgraduate @ Harish-Chandra Research Institute
Country: India

Title: Dimensional enhancements in a quantum battery with imperfections

Abstract:
We show that the average power output of a quantum battery based on a quantum interacting spin model, charged via a local magnetic field, can be enhanced with the increase of spin quantum number, thereby exhibiting dimensional advantage in quantum batteries. In particular, we demonstrate such increment in the power output when the initial state of the battery is prepared as the ground or canonical equilibrium state of the spin- j XY model and the bilinear-biquadratic spin- j Heisenberg chain (BBH) in presence of the transverse magnetic field and a weak value of interaction strength between the spins in the former model. Interestingly, we observe that in the case of the XY model, a tradeoff relation exists between the range of interactions in which the power increases and the dimension, while for the BBH model the improvements depend on the phase in which the initial state is prepared. Moreover, we exhibit that such dimensional advantages persist even when the battery Hamiltonian has some defects or when the initial battery state is prepared at finite temperature.

1. R. Alicki and M. Fannes, Phys. Rev. E 87, 042123 (2013).
2. A. C. Santos, B. Çakmak, S. Campbell, and N. T. Zinner, Phys. Rev. E 100, 032107 (2019).
3. S. Ghosh, T. Chanda, and A. Sen(De), Phys. Rev. A 101, 032115 (2020).
4. F. D. M. Haldane, Phys. Rev. Lett. 50, 1153 (1983).

I-32 Sungguen Ryu

Position and affiliation: Postdoc @ Instituto de Física Interdisciplinar y Sistemas Complejos
Country: Spain

Title: Quantum Consensus Dynamics by Entangling Maxwell Demon

Abstract:
We propose a new type of Maxwell demon that is capable of generating many-body entanglement in the working substance [1]. The entangling demon randomly selects a qubit pair among many and performs a quantum feedback control, in continuous repetitions. Such protocol realizes the quantum steady-state engineering [2] as studied in quantum information and optics. Previous studies have identified possible types of entangled states which are stabilizable [2,3]. However, the quantum dynamics, i.e. how entanglement, coherence, and von Neumann entropy evolve in time, still lacks understanding. The mechanism behind the quantum dynamics is nontrivial due to two simultaneous tasks, the random selection and the continuous quantum measurement.
We study the quantum dynamics and the second law of thermodynamics under the action of such entangling Maxwell demon. We first propose a quantum version of the voter model, an entangling Maxwell demon adopting a protocol inspired by the noisy voter model [4], motivated by the fact that the classical model generates classical correlation of human opinions among agents. Our first main finding is that Greenberger-Horne-Zeilinger (GHZ) entanglement is generated among the working substance and stabilized against the bit-flip noises. During the entanglement generation, the purity and the entropy of the working substance change non-monotonically in time, which turns out to be due to the competition between the quantum-classical mutual information gain [5] and the absolute irreversibility [6] of the

feedback control. We also find that the upper bounds for the entropy reduction and the work extraction are determined by the competition between the information gain and the absolute irreversibility. This suggests that a general condition for the operation of a successful entangling demon, one for which many-body entanglement stabilization and work extraction are possible, is that the information gain is larger than the absolute irreversibility.

[1] Sungguen Ryu, Rosa López, and Raúl Toral, arXiv:2102.00777, accepted in New J. Phys.
[2] F. Verstraete, M. M. Wolf, and J. I. Cirac, Nature Physics 5, 633–636 (2009).
[3] F. Ticozzi and L. Viola, Quantum Information & Computation 14, 265–294 (2014).
[4] A. F. Peralta, A. Carro, M. San Miguel, and R. Toral, New Journal of Physics 20, 103045 (2018).
[5] T. Sagawa and M. Ueda, Phy. Rev. Lett. 100, 080403 (2008).
[6] K. Funo, Y. Murashita, and M. Ueda, New Journal of Physics 17, 075005 (2015).

I-33 Tanmay Saha
Position and affiliation: Postgraduate @ The Institute of Mathematical Sciences, India
Country: India

Title: Quantum homogenization in non-Markovian collisional model

Abstract:
Collisional models are a category of microscopic framework designed to study open quantum systems. The framework involves a system sequentially interacting with a bath comprised of identically prepared units. In this regard, quantum homogenization is a process where the system state approaches the identically prepared state of bath unit in the asymptotic limit. Here, we study the homogenization process for non-Markovian collisional model generated via additional bath-bath interaction. With partial swap operation as both system-bath and bath-bath unitary, we show that homogenization is achieved irrespective of the initial states of the system or bath units. This is reminiscent of the Markovian scenario, where partial swap is the unique operation for a universal quantum homogenizer. On the other hand, we observe that the rate of homogenization is slower than its Markovian counterpart. Interestingly, a different choice of bath-bath unitary speeds up the homogenization process but loses the universality being dependent on the initial states of the bath units.

I-34 Tanoy Kanti Konar
Position and affiliation: Postgraduate @ Harish-Chandra Research Institute
Country: India

Title: Designing Robust Quantum Refrigerators in Disordered Spin Models

Abstract:
We explore a small quantum refrigerator in which the working substance is made of paradigmatic nearest neighbor quantum spin models, the *XYZ* and the *XY* model with Dzyaloshinskii-Moriya interactions, consisting of two and three spins, each of which is in contact with a bosonic bath. We identify a specific range of interaction strengths which can be tuned appropriately to ensure a cooling of the selected spin in terms of its local temperature in the weak coupling limit. Moreover, we report that in this domain, when one of the interaction strengths is disordered, the performance of the thermal machine operating as a refrigerator remains *almost* unchanged instead of degradation, thereby

establishing the flexibility of this device. However, to obtain a significant amount of cooling via ordered as well as disordered spin models, we observe that one has to go beyond weak coupling limit and compute the figures of merits by using global master equations.

1. Phys. Rev. Lett. 105, 130401 , Noah Linden, Sandu Popescu, and Paul Skrzypczyk
2. Phys. Rev. E 101, 012109 , Adam Hewgill, J. Onam González, José P. Palao, Daniel Alonso, Alessandro Ferraro, and Gabriele De Chiara
3. New J. Phys. 17 115013, Mark T Mitchison, Mischa P Woods, Javier Prior and Marcus Huber

I-35 Ruo Cheng Huang
Position and affiliation: Postgraduate @ Nanyang Technological University
Country: Singapore

Title: Work extraction from quantum systems with complex temporal correlations

Abstract:
Quantum information-processing techniques enable work extraction from a system's inherently quantum features, in addition to the classical free energy it contains. Meanwhile, the science of computational mechanics affords tools for the predictive modelling of non-Markovian classical and quantum stochastic processes.
We combine tools from these two sciences to develop a theoretical prototype for a predictive quantum engine: a machine that charges a battery by feeding on a multipartite quantum system whose parts are temporally correlated via a classical stochastic process. We also test the engine on simple models to benchmark the performance of our engine against various alternatives, including one without coherent quantum information-processing and one without predictive functionality; our predictive quantum engine is shown to outperform these alternatives in terms of work output.
Finally, we evaluate the engine's performance on fuel processes with different degrees of temporal correlations and find the work yield to increase with such correlations. Our results also suggest that any process with a parametric family of quantum outputs exhibits a phase boundary between parametric regions where memory of past observations can and cannot enhance the work yield. Our work opens the prospect of machines that harness environmental free energy in an essentially quantum, essentially time-varying form.

I-36 Ian Ford
Position and affiliation: Faculty @ UCL
Country: United Kingdom of Great Britain and Northern Ireland

Title: Stochastic entropy production for continuous measurements of open quantum systems

Abstract:
We investigate the stochastic total entropy production of an open quantum system undergoing continuous measurements. Instead of the traditional quantum measures for entropy, we have borrowed from stochastic thermodynamics to understand the entropy production associated with the probabilities of evolution of a (reduced) density matrix along stochastic trajectories under forward and reverse protocols defined by the time-dependent strength of the continuous measurements. The entropy production is expressed through a system and an environmental contribution, and is obtained from the

continuous stochastic dynamics of the density matrix. These arise, in our model, from the Markovian approximation of the stochastic Liouville-von Neumann equation for a two level system, where we impose environmental couplings that allow the system to explore the Bloch sphere in a quasi-isotropic way in the absence of measurement. Non-equilibrium production of entropy is observed as a result of measurement even when there is no change in the ensemble-averaged density matrix, which we regard as a crucial insight. We demonstrate thermalisation in accordance with the system Hamiltonian and environmental temperature, and the strict adherence of entropy production to a detailed fluctuation theorem.

I-37 Muzzamal Shaukat
Position and affiliation: Faculty @ National University of Sciences and Technology, Islamabad
Country: Pakistan

Title: Dark Soliton Qudit and Entanglement Dynamics, A novel quantum information platform in Bose-Einstein condensates

Abstract: We study the possibility of using dark-solitons in quasi one-dimensional Bose-Einstein condensates to produce two or three-level systems (qudits) by exploiting the intrinsic nonlinear and the coherent nature of the matter waves. More precisely, we intend to create the dark soliton qudits by using trapped impurities. The decoherence induced by the quantum fluctuations (phonons) produces a finite lifetime due to their intrinsic slow-time dynamics. 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. Further, we explore the spontaneous generation of phononic entanglement between dark soliton qubits in the dissipative process of spontaneous emission. By driving the qubits with the help of oscillating magnetic field gradient, we observe the formation of long-distance steady-state concurrence. Our results suggest that dark-soliton qubits are a good candidate for quantum information protocols based purely on matter-wave phononics.

I-38 Matteo Brunelli
Position and affiliation: Postdoc @ University of Basel
Country: Switzerland

Title: A unified collision model for coherent and measurement-based quantum feedback

Abstract:
Measurement-based feedback and coherent feedback design two broad classes of quantum feedback control. In the first, the information about the system to be controlled is gathered via measurements performed on a controller; this classical information is in turn used to close the feedback loop. In the second strategy, the controller stays quantum at all times, thus processing quantum information. In the current literature, it is often claimed that coherent feedback is inherently superior to measurement-based feedback. However, these comparisons often fail to explicitly model the feedback loop and/or to guarantee that the same amount of resources is available to both feedback operations.
We present a unified framework for describing coherent and measurement-based feedback loops as cascaded collision models. Collision models are a class of schemes for modelling open quantum dynamics where the system repeatedly interacts with an environment, which gets refreshed after each interaction. This approach allows us to explicitly model feedback loop as two successive system-controller

interactions, interspersed by either a measurement or a unitary operation on the controller.
We use this framework to compare the performance of coherent and measurement-based feedback in several key tasks for quantum control and quantum thermodynamics. We show that, typically, measurement-based feedback is superior in cooling, whilst coherent feedback is better at assisting quantum operations. We show that both coherent and measurement-based feedback loops mediated by partial swaps allow one to simulate arbitrary Hamiltonian evolutions, and discuss their respective effectiveness in this regard. We finally compare the performances of the two feedback strategies for stabilising a quantum battery in a charged state, protecting it from environmental dissipation.

I-40 Rishav Sagar
Position and affiliation: Postgraduate @ Indian Institute of Science Education and Research Berhampur
Country: India

Title: Fluctuations and Thermodynamic Uncertainty relations in Quantum Critical Engines

Abstract:
Recent works have focused on many-body heat engines at criticality. However, more studies are required in the design and control of such engines to increase their reliability and performance. The advantage of many-body quantum critical engines with N spins can be studied by comparing parameters like Noiseto-Signal ratio with the ensemble of N-single particle quantum heat engines (i.e by removing effects of interaction.). Study of out-of-equilibrium fluctuations have been theoretically and experimentally verified in two-level
systems and Harmonic oscillators. However, the Study of effects of criticality in presence of dissipative baths along with many-body effects may provide us with stable engines which can be experimentally implemented with an added advantage. Their performance stability can be optimized for a particular driving parameter. This will also contribute to noteworthy advancement in our understanding of non-equilibrium phenomena. This work is also aimed at studying the thermodynamic uncertainty relation to show the relation between average extracted work, fluctuations, and entropy production. This could contribute to understanding fundamental limits such as bounds on efficiency and power in quantum engines with many-body effects including criticality. Universal bounds on fluctuations under non-equilibrium conditions have been established recently.
However, the present study doesn't consider the many-body effect and it could be exciting to check the validity of these bounds in many-body quantum critical heat engines.
Output work, power, and efficiency have been shown to exhibit universal scaling in finite-time quantum critical heat engines. Further, a fundamental question to be asked could be whether far-from-equilibrium quantities like fluctuations in output work, power, etc. also follow such universal scaling laws. We plan to investigate these objectives in a quantum Otto-cycle with a transverse-field Ising model exhibiting QPT.

I-41 Varinder Singh
Position and affiliation: Postdoc @ Institute for Basic Science, Korea
Country: Korea, Republic of

Title: Thermodynamic uncertainty relation in nondegenerate and degenerate three-level maser heat engine

Abstract:

We investigate the thermodynamic uncertainty relation, which represents a trade-off between entropy production rate and relative power fluctuations, for non-degenerate three-level and degenerate four-level maser heat engine. For the non-degenerate case, we study two slightly different configurations of three-level maser engine and show that spontaneous emission plays an important role in determining the degree of violation of thermodynamic uncertainty relation. Further, for the degenerate four-level engine, we study the effects of noise-induced coherence on the thermodynamic uncertainty relation. We show that depending on the parametric regime of operation, the phenomenon of noise-induced coherence can either enhance or suppress the relative power fluctuations.

I-42 Oisín Culhane
Position and affiliation: Postgraduate @ Trinity College Dublin
Country: Ireland

Title: Extractable Work in Quantum Electromechanics

Abstract:
Recent experiments have demonstrated the generation of coherent mechanical oscillations in a suspended
carbon nanotube[1], which are driven by an electric current through the device above a certain voltage threshold, in close analogy with a lasing transition. We investigate this phenomenon from the perspective of work extraction, by modelling a nano-electromechanical device as a quantum flywheel or battery that converts electrical power into stored mechanical energy. We introduce a microscopic model that qualitatively matches the experimental finding, and compute the Wigner function of the quantum vibrational mode in its non-equilibrium steady-state. We characterise the threshold for self-sustained oscillations using two approaches to quantifying work deposition in non-equilibrium quantum thermodynamics: the ergotropy and the non-equilibrium free energy. We find that ergotropy serves as an order parameter for the phonon lasing transition. The framework we employ to describe work extraction is general and widely transferable to other mesoscopic quantum devices.

O. Culhane, M. T. Mitchison and J. Goold, "Extractable Work in Quantum Electromechanics", https://arxiv.org/abs/2201.07819
[1] Y. Wen, N. Ares, F. J. Schupp, T. Pei, G. A. D. Briggs, and E. A. Laird, “A coherent nanomechanical oscillator driven by single-electron tunnelling,” Nature Physics, vol. 16, pp. 75–82, Oct. 2019.

I-43 Dmitry Golubev
Position and affiliation: Faculty @ Aalto University
Country: Finland

Title: Thermoelectric current in a graphene Cooper pair splitter

Abstract:
Generation of electric voltage in a conductor by applying a temperature gradient is a fundamental phenomenon called the Seebeck effect. This effect and its inverse is widely exploited in diverse applications ranging from thermoelectric power generators to temperature sensing. Recently, a possibility of thermoelectricity arising from the interplay of the non-local Cooper pair splitting and the elastic co-tunneling in the hybrid normal metal superconductor-normal metal structures was predicted.

Here, we report the observation of the non-local Seebeck effect in a graphene-based Cooper pair splitting device comprising two quantum dots connected to an aluminum superconductor and present a theoretical
description of this phenomenon. The observed non-local Seebeck effect offers an efficient tool for producing entangled electrons.

Z. B. Tan, A. Laitinen, N. S. Kirsanov, A. Galda, V. M. Vinokur, M. Haque, A. Savin, D. S. Golubev, G. B. Lesovik, and P. J. Hakonen,
Thermoelectric current in a graphene Cooper pair splitter, Nat. Comm. 12, 138 (2021).

I-44 Björn Annby-Andersson

Position and affiliation: Postgraduate @ Lund University
Country: Sweden

Title: Quantum Fokker-Planck Master Equation for Continuous Feedback Control

Abstract:
Measurement and feedback is a powerful tool for controlling thermodynamic processes.
Here we develop a formalism describing continuously feedback-controlled quantum systems, including a realistic description of a detector with finite bandwidth. Our main result is a quantum Fokker-Planck master equation describing the joint system-detector time evolution. In particular, by separating the system and detector timescales, we can derive a Markovian master equation for the system state. The strength of this equation lies in its ability to analytically describe nonlinear feedback protocols, going beyond the
Markovian master equation derived by Wiseman and Milburn. A useful application, relevant for thermodynamic purposes, is the possibility of deriving fluctuation theorems from the Markovian description, providing insight into the interplay between thermodynamics and information theory. To highlight the usefulness of our formalism, we study two simple information engines, one classical and one quantum, extracting energy from two-level systems. We believe that the derived formalism will be a valuable asset in the thermodynamics community as it applies on a large variety of continuous feedback protocols, and describes how realistic detector conditions influence the success of the protocol.

I-45 Dominik Safranek

Position and affiliation: Postdoc @ Institute for Basic Science, South Korea
Country: Korea, Republic of

Title: Work extraction from unknown quantum sources

Abstract:
Ergotropy is one of the promising definitions of work extracted from a quantum system. Like other definitions, this definition requires full knowledge of the quantum state of the system. However, in real world the only way how to obtain this knowledge either requires creating the state, which costs at least as much as how much can be extracted or performing a full quantum state tomography on the source, which may be impractical, or impossible considering that one has to do many measurements, in many different non-orthogonal bases to achieve that. In a real-world situation, however, one would expect to do just a few measurements on an unknown source, and see how much work can be extracted by having

this limited information. We do exactly that: we define a scenario in which we have a completely unknown source, characterize it by a single type of measurement, and then determine how much work can be extracted: this is done by modifying the definition of ergotropy so it applies for this situation. This models real-life scenarios and goes much further into the practical usefulness of ergotropy as a realistic figure of merit.

I-46 Andrew Guthrie
Position and affiliation: Postdoc @ Aalto University
Country: Finland

Title: Towards a Quantum Otto Refrigerator in a Superconducting Circuit

Abstract:
Quantum heat engines and refrigerators provide a unique platform for studying quantum thermodynamics. Until now, a solid-state implementation of a quantum Otto refrigerator has remained elusive and would mark a significant milestone in the field. Here we present experiments towards a practical implementation of a quantum Otto cycle in a superconducting circuit. Our approach utilizes a gated Cooper-pair box qubit coupled to two superconducting coplanar waveguide resonators. By terminating the resonators by normal-metal heat reservoirs whose temperature can be controlled and monitored, a quantum refrigerator can be realized. We discuss the design and operation of this practical device and discuss the thermodynamic results within the framework of existing models of open-quantum systems.

I-47 Seyed Arash Ghoreishi
Position and affiliation: Postdoc @ RCQI, Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia
Country: Slovakia

Title: Minimum-error discrimination of thermal states

Abstract:
We study several variations of the question of minimum-error discrimination of thermal states. Besides of providing the optimal values for the probability error we also characterize the optimal measurements. For the case of a fixed Hamiltonian, we show that for a general discrimination problem the optimal measurement is the measurement in the energy basis of the Hamiltonian. We identify a critical temperature determining whether the given temperature is best distinguishable from thermal state of very high, or very low temperatures. Further, we investigate the decision problem of whether the thermal state is above, or below some threshold value of the temperature. Also, in this case, the minimum-error measurement is the measurement in the energy basis. This is no longer the case once the thermal states to be discriminated have different Hamiltonians. We analyze a specific situation when the temperature is fixed, but the Hamiltonians are different. For the considered case, we show the optimal measurement is independent of the fixed temperature and also of the strength of the interaction.

I-48 Santhos Terdale
Position and affiliation: Faculty @ Savitribai Phule Pune University

Country: India

Title: Thermodynamic studies of binary aqueous phosphonium based ionic liquids

Abstract: The depiction of energetics that exists between the molecules of IL requires the study of electrostatic permittivity of the medium in which they are immersed. There are many theories and models used to describe the physical and thermodynamic properties of electrolyte solutions. The concentration dependent thermodynamic properties of aqueous electrolyte solutions at infinite dilution are studied by Debye-Hückel theory and Pitzer model based theory. The thermodynamic properties of binary aqueous solutions of alkyl substituted phosphonium based ionic liquids (ILs) containing inorganic ions, amino acids or fatty acids as anions will be discussed. From the experimental measurement of osmotic property, water activity (aw), vapor pressure (p), mean molal activity coefficients (±), Gibbs free energy due to mixing (Gmix) and excess Gibbs free energy change (GE) due to mixing were calculated. Further, the correlation of the activity coefficient data with McMillan-Mayer theory and Pitzer model will be demonstrated and interpreted in terms of intermolecular interactions and structural characteristics of ILS.

I-49 Nicoletta Carabba
Position and affiliation: Postgraduate @ University of Luxemburg
Country: Luxemburg

Title: Ultimate Speed Limit to the Growth of Operator Complexity

Abstract: TBA

Session II

II-01 Alexssandre de Oliveira Junior
Position and affiliation: Postgraduate @ Jagiellonian university
Country: Poland

Title: A resource-theoretic approach to the thermodynamic arrow of time and its applications

Abstract:
The second law of thermodynamics imposes a fundamental asymmetry in the flow of events, called the arrow of time. It introduces an ordering on the space of states composed of three regions: future, incomparable, and past. In this work, we analyse the structure of the thermodynamic arrow of time within a resource-theoretic framework, where one investigates the accessibility of quantum state transformations under thermodynamic constraints. Specifically, for a given energy-incoherent state in the presence of a thermal bath, we found the necessary and sufficient conditions to construct its future and, more importantly, incomparable and past thermal cones. While the future thermal cone generalises Birkhoff's polytope, the past and incomparable cone can be considered an extension of the latter. Moreover, our findings also allow us to study important thermodynamic protocols, such as catalytic transformation, cooling processes and routes to thermalisation.

II-02 Michael Kewming
Position and affiliation: Postdoc @ Trinity College Dublin
Country: Ireland

Title: Entropy Production at Zero Temperature

Abstract:
Fluctuation theorems allow one to make generalised statements about the behaviour of thermodynamic quantities in systems that are driven far from thermal equilibrium. In this talk, I'll present our recent results where we use Crooks' fluctuation theorem to understand the entropy production of a continuously measured, zero-temperature quantum system; namely an optical cavity measured via homodyne detection.
At zero temperature, if one uses the classical definition of inverse temperature b, then the entropy production becomes divergent. Our analysis shows that the entropy production can be well defined at zero temperature by considering the entropy produced in the measurement record. We link this result to the Cramér-Rao inequality and show that the product of the Fisher information in the work distribution with the entropy production is bounded below by the square of the inverse energy fluctuations. This inequality indicates that there is a minimal amount of entropy production that is paid to acquire information about the work done to a quantum system driven far from equilibrium via quantum measurement.
In this talk, I will present a pedagogical derivation of this result and argue that thermodynamics quantities should be best understood through the lens of quantum measurements, and the associated fluctuations in these quantum measurement records.

M. Kewming and S. Shrapnel, Entropy Production at Zero Temperature, arXiv:2109.01998, (2021).

II-03 Anthony Kiely

Position and affiliation: Postdoc @ University College Dublin
Country: Ireland

Title: Entropy production in quantum control

Abstract:
Protocols for non-adiabatic quantum control invariably involve the use of time varying classical fields. Assessing the thermodynamic cost of such protocols, however, is far from trivial, with several non-equivalent measures proposed in the literature. Here we study the irreversible entropy produced by the classical apparatus generating the control fields. This associates the cost of a given control protocol with the dissipation. We focus, in particular, on the case of time-dependent magnetic fields and shortcuts to adiabaticity. We showcase our results with two examples: a Landau-Zener model of a spin 1/2 particle in a magnetic field and an ion confined in a Penning trap.

II-04 Paolo Andrea Erdman

Position and affiliation: Postdoc @ Freie Universität Berlin, Department of Mathematics and Computer Science, Arnimallee 6, 14195, Berlin, Germany
Country: Germany

Title: Identifying optimal cycles in quantum thermal machines with reinforcement-learning

Abstract:
Driven thermal machines, such as heat engines and refrigerators, allow us to control the conversion between heat and work through time-dependent controls that are periodically driven to implement thermodynamic cycles.
The performance of stochastic/quantum thermal machines is mainly characterized by power, efficiency, and power fluctuations. However, optimizing such quantities is an extremely challenging task: in finite-time, the state can be driven far from equilibrium, and cycle optimization is a search over the exponentially large space of all possible time-dependent controls. While general results have been found in the slow [1] and fast [2] driving regime – general finite-time optimization schemes are currently lacking.
We introduce a general framework based on Reinforcement Learning (RL) to discover optimal cycles that maximize the power of quantum thermal machines [3]. Our method makes no assumptions on the shape or speed of the cycle. Rather, the RL agent is free to arbitrarily couple the quantum system to any bath, and to arbitrarily manipulate the controls.
We apply our method, based on state-of-the-art RL algorithms, to three systems: a benchmark two-level system heat engine, where we find the known optimal cycle [4]; a refrigerator based on a superconducting qubit, where we find a non-intuitive control sequence that outperforms previous proposals; a heat engine based on a quantum harmonic oscillator, where we find an elaborate cycle that outperforms Otto cycles. We show that such cycles mitigate the detrimental effect of generation of coherence [5].
At last, I briefly discuss extensions of our method to:
- optimize the full trade-off between power, efficiency, and fluctuations [6]. We apply such method to a quantum dot-based engine and test the validity of the thermodynamic uncertainty relations [7] in finite-time driven engines.

- Identify optimal cycles only observing the heat currents, thus potentially applicable to experimental devices [8].

[1] P. Abiuso and M. Perarnau-Llobet, Phys. Rev. Lett. 124, 110606 (2020).
[2] V. Cavina, P.A. Erdman, P. Abiuso, L. Tolomeo, and V. Giovannetti, Phys. Rev. A 104, 032226 (2021).
[3] P.A. Erdman and F. Noé, NPJ Quantum Inf. 8, 1 (2022).
[4] P.A. Erdman, V. Cavina, R. Fazio, F. Taddei, and V. Giovannetti, New J. Phys. 21, 103049 (2019).
[5] R. Kosloff and T. Feldmann, Phys. Rev. E 65, 055102 (2002).
[6] P.A. Erdman, P. Abiuso, A. Rolandi, F. Noé, and M. Perarnau-Llobet, in preparation (2022).
[7] A.C. Barato and U. Seifert, Phys. Rev. Lett. 114, 158101 (2015).
[8] P.A. Erdman and F. Noé, in preparation (2022).

II-05 Ettore Bernardi

Position and affiliation: Faculty @ INRiM
Country: Italy

Title: Emergence of Constructor-based Irreversibility in Quantum Systems

Abstract:
Irreversibility can be expressed as the requirement that a transformation can be realised limitlessly well by a system operating in a cycle, while its inverse cannot. The idea of a cycle performing a transformation was generalised by von Neumann's constructor, i.e., a system able to perform a given task on another system while retaining the ability to do it again with arbitrary accuracy. This idea was recently explored and extended within the so-called constructor theory [1], where irreversibility can be expressed as the requirement that a constructor exists for a certain task, but not for its inverse [2].
We demonstrate the compatibility of such irreversibility with quantum theory's time-reversal symmetric laws, using a dynamical model based on the universal quantum homogeniser, experimentally implemented by means of a quantum optical setup exploiting high-quality single-photon qubits. In this way, we show how the fact that a constructor exists for a certain task (i.e., the transformation of a pure state in a maximally-mixed one) does not imply the same for its inverse (i.e., the passage from a maximally-mixed state to a pure one).

[1] D. Deutsch and C. Marletto, Constructor theory of information, Proc. R. Soc. A 471, 20140540 (2015).
[2] C. Marletto et al., Emergence of Constructor-based Irreversibility in Quantum Systems: Theory and Experiment, (2022) Phys. Rev. Lett. 128, 080401.

II-06 Rafael Sanchez

Position and affiliation: Faculty @ Universidad Autónoma de Madrid
Country: Spain

Title: Superconducting correlations induced heat engine in hybrid quantum dot

Abstract:
The energy absorbed by a conductor from a non-equilibrim environment can be rectified to generate finite electrical power. Typically, this depends on tiny energy-dependent asymmetries of the device, e.g. a quantum dot [1]. We show that larger currents are expected in hybrid systems, where a

superconductor hybridizes even-parity states (with 0 and 2 electrons) in the quantum dot. We consider the environment to consist on a quantum dot Coulomb-coupled to the conductor one and tunnel-coupled to a hot reservoir. Two main mechanisms contribute to the generation of power. On one hand, the non-equilibrium charge fluctuations in the second dot correlate with the Andreev processes hence injecting Cooper pairs in the superconductor. This provides the necessary symmetry breaking energy transfer. On the other hand, this mechanism competes with quasiparticle contributions, which benefit from the sharp features of the superconducting density of states and is able to increase the engine performance [3].

[1] H. Thierschmann et al., Nature Nanotech. 10, 854 (2015)
[2] S. M. Tabatabaei, D. Sánchez, A. Levy Yeyati and R. Sánchez, Phys. Rev. Lett. 125, 247701 (2020)
[3] S. M. Tabatabaei, D. Sánchez, A. Levy Yeyati and R. Sánchez, in preparation.

II-07 Eoin O'Connor

Position and affiliation: Postgraduate @ University College Dublin
Country: Ireland

Title: Stochastic Collisional Quantum Thermometry

Abstract:
Accurately determining the temperature of a physical system is a ubiquitous task. For quantum systems, measuring the temperature becomes a significantly more involved job, in part due to the inherent fragility of quantum states, and the fact that temperature itself is not a quantum observable. We extend collisional quantum thermometry schemes to allow for stochasticity in the waiting time between successive collisions. We establish that introducing randomness through a suitable waiting time distribution, the Weibull distribution, allows us to significantly extend the parameter range for which an advantage over the thermal Fisher information is attained. These results are explicitly demonstrated for dephasing interactions and also hold for partial swap interactions. Furthermore, we show that the optimal measurements can be performed locally, thus implying that genuine quantum correlations do not play a role in achieving this advantage. We explicitly confirm this by examining the correlation properties for the deterministic collisional model.

O'Connor, E., Vacchini, B., & Campbell, S. (2021). Stochastic collisional quantum thermometry. Entropy, 23(12), 1634.

II-08 José Balduque-Pizazo

Position and affiliation: Postgraduate @ Universidad Autónoma de Madrid
Country: Spain
Title: Resonant tunneling energy harvesters: improving performance via quantum interference

Abstract:
The spectral filtering of quantum dots can be used for heat to power conversion in electronic conductors. A proposal based on resonant-tunneling three-terminal devices [1] has been recently verified experimentally [2]. Two quantum dots connect the two terminals of a conductor to a hot electronic cavity where carriers exchange heat via thermalization. We propose the heat source to be

separated from the conductor via a beam-splitter (e.g., the tip of a scanning microscope) that mediates the system-bath coupling. The resulting ballistic electron propagation gives rise to interferences [3] able to improve the engine performance, both in the extracted power and the efficiency [4].

[1] A. N. Jordan, B. Sothmann, R. Sánchez and M. Büttiker, Phys. Rev. B 87, 075312 (2013)
[2] G. Jaliel et al., Phys. Rev. Lett. 123, 117701 (2019)
[3] R. Sánchez, C. Gorini and G. Fleury, Phys. Rev. B 104, 115430 (2021)
[4] J. Balduque Picazo, R. Sánchez, in preparation.

II-09 Jorge Tabanera-Bravo
Position and affiliation: Postgraduate @ Universidad Complutense de Madrid (UCM)
Country: Spain

Title: TBA

Abstract:
Collisional reservoirs are becoming a remarkable tool in the field of Open Quantum Systems due to their capacity to simulate thermal interactions in a relatively simple way. The more common implementation of these reservoirs consists on a repeated interaction of the target quantum system, S, with identical copies of ancillary systems called units, U . These units are refreshed into a thermal state after each interaction, mimicking the action of the thermal bath. However, the continuous switching on and off of the interaction between the system and the units provides additional energy to the system. This external work prevents thermalization in certain cases [1], yielding spurious currents and the violation of the second law.
This situation is treated in a serie of works [2,3,4,5]. There is shown how the introduction of the kinetic degree of freedom of the units, p, makes the whole setup autonomous. The unit state is then a narrow wave packet with random momentum, Fig.1. In this case, the energy to switch on and off the interaction is provided by the spatial degree of freedom of the unit. If the momentum is in equilibrium, the energy exchange is no longer work, but heat, and the system thermalizes [2,3,5]. As a result, this approach captures all the essential features of a genuine thermostat.

[1] Barra, F. (2015). The thermodynamic cost of driving quantum systems by their boundaries. Scientific reports, 5(1), 1-10.
[2] Ehrich, J., Esposito, M., Barra, F., Parrondo, J. M. (2020). Micro-reversibility and thermalization with collisional baths. Physica A: Statistical Mechanics and its Applications, 552, 122108.
[3] Jacob, S. L., Esposito, M., Parrondo, J. M., Barra, F. (2021). Thermalization induced by quantum scattering. PRX Quantum, 2(2), 020312.
[4] Jacob, S. L., Esposito, M., Parrondo, J. M., Barra, F. (2021). Quantum scattering as a work source. arXiv preprint arXiv:2108.13369.
[5] Tabanera, J., Luque, I., Jacob, S. L., Esposito, M., Barra, F., Parrondo, J. M. (2022). Quantum collisional thermostats. New Journal of Physics.

II-10 Varazdat Stepanyan
Position and affiliation: Undergraduate @ Yerevan State University, Yerevan Physics Institute
Country: Armenia

Title: Photon cooling: linear vs nonlinear interactions

Abstract: Linear optics imposes a relation that is more general than the second law of thermodynamics: For modes undergoing a linear evolution, the full mean occupation number (i.e. photon number for optical modes) does not decrease, provided that the evolution starts from a diagonal state. This relation connects to noise-increasing (or heating), and is akin to the second law, though for the linear evolution it holds for a wider set of initial states. We show that this general trend can be reversed via nonlinear interactions between the modes. They can cool -- i.e. decrease the full mean occupation number and the related noise -- an equilibrium system of modes provided that their frequencies are different. Such an effect cannot exist in energy cooling, where only a part of an equilibrium system is cooled. We describe the cooling set-up via both efficiency and coefficient of performance, and relate the cooling effect to the Manley-Rowe theorem in nonlinear optics.

II-11 Guilherme de Sousa
Position and affiliation: Postgraduate @ University of Maryland, College Park
Country: United States of America

Title: Quantum harmonic oscillator under measurement and feedback

Abstract:
In order to control and manipulate quantum systems it is often necessary to apply measurement and feedback. Applications of quantum technology depend on these features and a theoretical understanding is necessary to correctly simulate quantum dynamics. Recently a Quantum Fokker-Planck Master Equation (QFPME) was derived for the joint distribution of system and detector (Annby-Andersson et al, arXiv:2110.09159). This generalized master equation contains the feedback dynamics for the system of interest but also distributions of detector variable for many realizations of the experiment. The main ingredients for that are the measurement backaction that disturbs the system and the detector bandwidth that accounts for how fast the measurement apparatus can keep up with system dynamics. For a generic system, the QFPME is only suitable for numerical solutions; for the specific case of separation of time scales, when the detector is very fast compared to the internal dynamics of the system, one can derive an effective master equation for the system alone. Here we apply this formalism to the quantum harmonic oscillator. Results were derived for arbitrary values of the parameters, without relying on the assumption of separation of timescale. We found analytical results for the position measurement and cooling protocol. The optimal protocol depends on a precise choice of the ratio between the measurement strength and detector lag. That indicates a trade-off between measurement disturbance and how much information one can collect and process to correctly apply the feedback. Our results provide intuition into quantum measurement and feedback and illustrate how to apply this new master equation for continuous quantum systems.

[1] B. Annby-Andersson, F. Bakhshinezhad, D. Bhattacharyya, G. De Sousa, C. Jarzynski, P. Samuelsson, P. P. Potts. Quantum Fokker-Planck master equation for continuous feedback control. arXiv:2110.09159.
[2] H. M. Wiseman and G. J. Milburn. Quantum theory of optical feedback via homodyne detection. Phys. Rev. Lett. 70, 548.
[3] K. Jacobs and D. A. Steck. A straightforward introduction to continuous quantum measurement. Contemporary Physics, 47:5, 279-303.

II-12 Gabriel Oliveira Alves

Position and affiliation: Postgraduate @ University of São Paulo
Country: Brazil

Title: Bayesian estimation for collisional thermometry

Abstract:
Quantum thermometry exploits the high level of control in coherent devices to offer enhanced precision for temperature estimation. This highlights the need for constructing concrete estimation strategies. Of particular importance is collisional thermometry, where a series of ancillas are sent sequentially to probe the system's temperature. In this paper we put forth a complete framework for analyzing collisional thermometry using Bayesian inference. The approach is easily implementable and experimentally friendly. Moreover, it is guaranteed to always saturate the Cramer-Rao bound in the long-time limit. Subtleties concerning the prior information about the system's temperature are also discussed, and analyzed in terms of a modified Cramer-Rao bound associated to Van Trees and Schützenberger.

Alves, G.O.; Landi, G.T. Bayesian estimation for collisional thermometry. arXiv 2021, arXiv:2106.12072

II-13 André Hernandes Alves Malavazi

Position and affiliation: Postgraduate @ University of São Paulo
Country: Brazil

Title: Energetics within autonomous quantum systems

Abstract:
During the last decades, the development of a thermodynamic theory for quantum systems has been receiving a great deal of attention, especially from a technological perspective. In this sense, a thermodynamic description applicable to such systems is imperative for designing and developing genuine quantum technologies. Nevertheless, despite the rapid development and rising efforts, there are still subtle and fundamental questions to be answered. Along these lines, it is still unclear how to properly define and establish consistent and general quantum versions of classical thermodynamic concepts and quantities, such as work, heat, entropy and even internal energy. Such a critical lack of consensus intensifies once dealing with open quantum systems in general contexts. In particular, when one analyzes coupling scenarios beyond the approximative regimes and orthodox thermodynamic settings. In this work, we are interested in addressing such fundamental questions. More specifically, we introduce a novel approach for describing the energetic exchange within general autonomous bipartite quantum systems. The formal structure of this proposal is exact and allows the definition of local effective Hamiltonians for characterizing the subsystem's internal energies. This description guarantees symmetrical treatment of the bipartitions and, most importantly, also automatically preserves the thermodynamic notion of energy additivity. In contrast with current methodologies, such a framework does not rely on approximations, particular coupling regimes or additional hypotheses of this kind. Moreover, the obtained expressions also establish a new route for defining other general thermodynamic quantities to the quantum realm, such as work and heat.

II-14 Habib Aissaoui
Position and affiliation: Faculty @ LPMPS, Physics Dept. Faculty of Fundamental Sciences, University of Constantine 1, Constantine
Country: Algeria

Title: Strong first-order phase transition and B-violation in the compact 341 model.

Abstract:
Baryogenesis in the context of the compact SU(3)C⊗SU(4)L⊗U(1)X model is investigated. Using the finite temperature effective potential approach together with unitarity, stability and no ghost masses constraints, the existence of a strong first order electroweak phase transition (EWPT) was shown and checked numerically during all steps of the spontaneous breakdown of the gauge symmetry of the model. Higgs masses regions fulfilling the EWPT criteria are also discussed. Moreover, and as a byproduct of our study, the B-violation via sphaleron was also emphasized.

II-15 Arpan Das
Position and affiliation: Postdoc @ Nicolaus Copernicus University, Toruń, Poland
Country: Poland

Title: Fluctuations in periodically modulated continuous quantum thermal machines

Abstract:
We use Floquet formalism to study fluctuations in continuous quantum thermal machines. The thermodynamic uncertainty ratio shows a minimum at the heat engine to refrigerator transition point. We also study fluctuations in the efficiency of such machines; the fluctuations are bounded from both above and below in the heat engine regime, while open questions remain in case of refrigerators.

II-16 Brecht Donvil
Position and affiliation: Postdoc @ Ulm University
Country: Germany

Title: Fluctuation relation for general time local master equations

Abstract:
General time local master equations are master equations of the Lindblad form with rates that are not positive definite. They naturally arise from exactly solvable models or from time-convolutionless perturbation theory. Lindblad equations can always be unravelled in terms of stochastic jump equations for the state vector, for general time local master equations this scheme does not work. Recently the usual unravelling scheme was extended to general time local master equations by introducing a scalar variable $\mu(t)$, the influence martingale, whose dynamics are enslaved to the dynamics of the state vector [1]. The system state $\rho(t)$ is then reproduced by the Monte Carlo average
$\rho(t) = \langle \mu_t \psi(t) \psi^\dagger(t) \rangle$
We use the unravelling scheme developed in [1] to derive a fluctuation relation for the dynamics generated by general time local master equations. Concretely, we find a trajectory dependent functional $\mathcal{A}$ such that when averaged over all realisations $\langle \mathcal{A} \rangle = 1$. Contrary to the Lindblad case, the functional $\mathcal{A}$ is not positive definite. If we split up the $\langle \mathcal{A} \rangle$ in positive and negative contributions we can write

$\langle \mathcal{A} \rangle = \langle e^{-S_+} \rangle_+ - \langle e^{-S_-} \rangle_- = 1.$
Thus we can interpret the fluctuation relation to arise from two distinct stochastic processes.
We link this result to the Wittstock-Paulsen decomposition for completely bounded maps Completely bounded maps are a more general class of maps than completely positive maps, which include maps generated by general time local master equations.
The Wittstock-Paulsen decomposition states that any completely bounded map Λ can be written as the difference of two completely positive maps $\Lambda_\pm$, i.e. $\Lambda = \Lambda_+ - \Lambda_-$.

[1] B. Donvil and P. Muratore-Ginanneschi, arXiv:2102.10355 (2021)

II-17 George Thomas
Position and affiliation: Postdoc @ Aalto university, Finland
Country: Finland

Title: Thermally pumped maser and three terminal heat transport with superconducting circuits

Abstract:
We present a theoretical model of an on-chip thermally pumped three-level maser in a superconducting circuit based on a single artificial atom [1]. With typical circuit parameters, the maser powers of the order of a few femtowatts, can be achieved. We also demonstrate a method to detect the population inversion in the artificial atom from the influx of heat power into a weakly coupled output terminal. For that purpose, the system should operate as a three-terminal heat transport device. The proposed method of on-chip conversion of heat into microwave radiation and control of energy-level populations by heating provide additional useful tools for circuit quantum electrodynamics experiments. We will also discuss recent experimental realization of a three-terminal photonic heat transport device [2].

[1] G. Thomas, A.Gubaydullin, D. S. Golubev, and J.P. Pekola Phys. Rev. B 102, 104503 (2020).
[2] A. Gubaydullin, G. Thomas, D. S. Golubev, D. Lvov, J. T. Peltonen, and J.P. Pekola arXiv:2112.09224 (accepted in nature communications, 2022).

II-18 Heather Leitch
Position and affiliation: Postgraduate @ Queen's University Belfast
Country: United Kingdom of Great Britain and Northern Ireland
Title: Driven quantum harmonic oscillators: A working medium for thermal machines

Abstract:
The study of quantum thermodynamics is key to the development of quantum thermal machines and understanding their potential advantages over their classical counterparts.
We investigate a working medium consisting of parametrically driven quantum harmonic oscillators coupled to heat baths via a collision model. From the resulting heat flows and power of the working device, we find that it may operate as an engine, refrigerator, or accelerator. Studying both slow and fast driving regimes, we discover that increasing the driving frequency not only leads to a change in functioning, but also the addition of new operations not possible with slow driving.
We find that applying squeezing to one of the thermal baths leads to an apparent higher efficiency compared to the corresponding Carnot value of an equilibrium bath with the same temperature.
Furthermore, we conclude that squeezing is a necessary requirement for the sustained generation of

entanglement within a system of two driven dissipative QHO's, and controlled driving of the system's oscillators can increase the degree of entanglement.

II-19 Jesús Rubio

Position and affiliation: Postdoc @ University of Exeter
Country: United Kingdom of Great Britain and Northern Ireland

Title: Precision matters: from quantum thermometry to the quantum estimation of scales, and back

Abstract:
Whether quantum technologies are ultimately successful will crucially depend on our ability to perform extremely precise measurements. This mindset has recently led to an in-depth revision of the foundations of quantum thermometry, culminating in a Bayesian reformulation of the fundamental precision limits in temperature estimation. In this talk, the new framework of quantum thermometry is decoupled from its thermodynamic origin and extended it as to accommodate the estimation of any scale in physics---temperature or otherwise. The key novelty is the explicit construction of the positive operator-valued measure which is optimal for a given state. Upon reintroducing the language of equilibrium thermometry, scale estimation is shown to establish the optimality of energy measurements regardless of the initial state of information. It is then discussed how can this result bridge the gap between the range of current approaches to Bayesian quantum thermometry and the full power of quantum estimation theory. On a fundamental note, it is argued that quantum scale estimation completes a trio of metrological frameworks for the most elementary quantities that one could possibly measure: phases, locations and scales.

J. Rubio, Quantum Scale Estimation, arXiv:2111.11921 (2021); J. Rubio, J. Anders and L. A. Correa, Global Quantum Thermometry, Phys. Rev. Lett., 127:190402 (2021)

II-20 Jonas Glatthard

Position and affiliation: Postgraduate @ University of Exeter
Country: United Kingdom of Great Britain and Northern Ireland

Title: Improved release–recapture thermometry with adaptive Bayesian techniques

Abstract:
Release–recapture thermometry is extensively used to measure the temperature of ultracold atomic clouds. The potential confining the atoms is switched off for a controlled time and the number of recaptured atoms is measured. Varying the release–recapture time allows to make a fit of the data to a theoretical model for the survival probability. Here, we process experimental data from potassium atoms in a tweezer trap with the newly introduced Bayesian framework of global quantum thermometry. To do that we develop a probabilistic model which accounts for fluctuations in the number of recaptured atoms, taking into account also the uncertainty in the initial number of atoms. We show that choosing the release–recapture time according to an adaptive Bayesian strategy, which maximises the information gain per measurement, substantially reduces the number of measurements needed to converge to an accurate temperature estimate. Furthermore, we show that the adaptive–Bayesian method produces much more reliable estimates, especially when the data are scarce and noisy.

II-21 Mar Ferri Cortes
Position and affiliation: Postgraduate @ IFISC
Country: Spain

Title: Inefficiency in continuous monitoring of quantum systems

Abstract:
In open quantum systems, in order to establish the impact of quantum fluctuations during the evolution of a system, one needs to continuously monitor it while minimizing disturbance. The thermodynamics of systems which are subjected to continuous quantum measurement can be described using the formalism of quantum trajectories. However, in realistic scenarios, this measurement is not ideal: detectors have finite efficiency and some processes elude monitoring. Therefore the efficiency of the measurement or detector should be considered and introduced in the thermodynamic account. We study how these effects can be added to the system evolution and how they affect main thermodynamic quantities, such as work, heat or entropy production in generic non-equilibrium processes. We focus particularly on the impact over the microreversibility and fluctuation theorems. The results to be obtained could be used to study more realistic systems and processes often used in quantum technologies to assess their thermodynamic costs.

G. Manzano, R. Zambrini. "Quantum thermodynamics under continuous monitoring: a general framework", arXiv:2112.02019

II-22 Muhammad Tahir Nasseem
Position and affiliation: Postgraduate @ Koc University Istanbul, Turkey.
Country: Turkey

Title: Ground-state cooling of mechanical resonators by quantum reservoir engineering

Abstract:
Ground-state cooling of multiple mechanical resonators becomes vital to employ them in various applications ranging from ultra-precise sensing to quantum information processing. Here we propose a scheme for simultaneous cooling of multiple degenerate or near-degenerate mechanical resonators to their quantum ground-state, which is otherwise a challenging goal to achieve. As opposed to standard laser cooling schemes where coherence renders the motion of a resonator to its ground-state, we consider an incoherent thermal source to achieve the same aim. The underlying physical mechanism of cooling is explained by investigating a direct connection between the laser sideband cooling and "cooling by heating". Our advantageous scheme of cooling enabled by quantum reservoir engineering can be realized in various setups, employing parametric coupling of a cooling agent with the target systems. We also discuss using non-thermal baths to simulate ultra-high temperature thermal baths for cooling.

Communications Physics 4 (1), 1-10 (2021).

II-23 Léonce Dupays
Position and affiliation: Undergraduate @ University of Luxembourg
Country: Luxembourg

Title: Quantum Control of 1D gases

Abstract:
Many-body quantum systems in low spatial dimensions are characterized by enhanced correlations with respect to their three-dimensional counterparts. Interactions and quantum statistics are ill-defined as independent concepts in one spatial dimension, where the canonical Fermi liquid theory breaks down. In this setting, the Tomonaga-Luttinger liquid (TLL) provides a universal low-energy description of interacting fermions [1, 2] in terms of bosonic collective degrees of freedom [3]. Due to its broad applicability, the TLL has been used as a testbed for nonequilibrium quantum phenomena in theoretical and experimental studies. We explore the dynamics of the TLL model during an interaction quench and provide control protocols to engineer a prescribed trajectory for the driven TLL. This works finds a direct relevance in quantum thermodynamics with possible application of an interaction driven heat engine.

[1] S.-i. Tomonaga, Progress of Theoretical Physics 5, 544 (1950).
[2] J. M. Luttinger, Journal of Mathematical Physics 4, 1154 (1963), https://doi.org/10.1063/1.1704046.
[3] D. C. Mattis and E. H. Lieb, Journal of Mathematical Physics 6, 304 (1965).

II-24 Lorenzo Buffoni
Position and affiliation: Postdoc @ Instituto de Telecomunicações, University of Lisbon
Country: Portugal

Title: Third law of thermodynamics and the scaling of quantum computers

Abstract:
The third law of thermodynamics, also known as the Nernst unattainability principle, puts a fundamental bound on how close a system, whether classical or quantum, can be cooled to a temperature near absolute zero. On the other side, a fundamental assumption of quantum computing is to start any computation from a register of qubits initialized in a pure state at zero temperature. This problem at the interface between quantum computing and thermodynamics is often overlooked or, at best, addressed only at a single-qubit level. Here, we will argue how the existence of a small, but finite, effective temperature, which makes the initial state a mixed state, poses a real challenge for the scaling of quantum computers. The theory, carried out for a generic quantum circuit with N-qubits input states, is validated by experiments performed on an IBM quantum computer.

II-25 Parth Kumar
Position and affiliation: Postgraduate @ The University of Arizona
Country: United States of America

Title: On the First Law of Thermodynamics in Time-Dependent Open Quantum Systems

Abstract:
An unambiguous operator is established for the internal energy of an interacting time-dependent open quantum system, shedding light on a long-standing debate about how exactly the First Law of Thermodynamics should be formulated for such systems[1-4]. We arrive at this using a key insight from Mesoscopics: infinitely far away from the local driving and coupling of an open quantum system,

reservoirs are only infinitesimally perturbed from equilibrium[5], allowing one to unambiguously define Heat in strongly driven systems. General expressions for the quantum-statistical averages of the heat current and the power delivered by various agents to an interacting Fermionic system are derived using Non-Equilibrium Green's Functions, establishing an experimentally meaningful and quantum mechanically consistent division of the energy of the system under consideration into Heat flowing from and Work done on the system. Our thermodynamic analysis also readily includes phonons and electron-phonon interactions and their effect on the first law is investigated. Motivated by previous work[6], we apply our formalism to analyze the thermodynamic performance of a model quantum machine: a driven two-level quantum system strongly coupled to two metallic reservoirs, which can operate in several configurations–as a chemical pump/engine and a heat pump/engine by leveraging Rabi Oscillations of the system. We present a detailed analysis of its operation as a chemical pump and a heat engine, the latter of which performs at 53% of Carnot efficiency for the parameters chosen.

[1] P. Strasberg and A. Winter, "First and Second Law of Quantum Thermodynamics: A Consistent Derivation Based on a Microscopic Definition of Entropy," 2021
[2] M. F. Ludovico, J. S. Lim, M. Moskalets, L. Arrachea, and D. Sanchez, "Dynamical energy transfer in ac-driven quantum systems," 2014
[3] A. Bruch, M. Thomas, S. Viola Kusminskiy, F. von Oppen, and A. Nitzan, "Quantum thermodynamics of the driven resonant level model," 2016
[4] P. Talkner and P. Hanggi, "Colloquium : Statistical mechanics and thermodynamics at strong coupling: Quantum and classical," 2020
[5] H. U. Baranger and A. D. Stone, "Electrical linear-response theory in an arbitrary magnetic field: A new Fermi-surface formation," 1989
[6] C. A. Stafford and N. S. Wingreen, "Resonant Photon-Assisted Tunneling through a Double Quantum Dot: An Electron Pump from Spatial Rabi Oscillations," 1996

II-26 Pierpaolo Sgroi
Position and affiliation: Postgraduate @ Centre for Theoretical Atomic, Molecular and Optical Physics, School of Mathematics and Physics, Queen's University Belfast, Belfast BT7 1NN, United Kingdom
Country: United Kingdom of Great Britain and Northern Ireland

Title: Modelling mechanical equilibration processes of closed quantum systems: a case-study

Abstract:
I will present my work on the study of a closed quantum system brought out of mechanical equilibrium, undergoing a non-driven, spontaneous, thermodynamic transformation [1]. In that work we consider a quantum particle in a box with a moving and insulating wall, subjected to a constant external pressure. Under the assumption that the wall undergoes classical dynamics, we obtain a system of differential equations that describes the evolution of the quantum system and the motion of the wall. We study the dynamics of such system and the thermodynamics of the process of compression and expansion of the box. Our approach is able to capture several properties of the thermodynamic transformations considered and goes beyond a description in terms of an ad-hoc time-dependent Hamiltonian, considering instead the mutual interactions between the dynamics of the quantum system and the parameters of its Hamiltonian.

[1] P. Sgroi and M. Paternostro, "Modelling mechanical equilibration processes of closed quantum systems: a case-study", Phys. Rev. E 105, 014127 (2022)

II-27 Juliette Monsel

Position and affiliation: Postdoc @ Chalmers University of Technology
Country: Sweden

Title: Geometric energy transport and refrigeration with driven quantum dots

Abstract:
Thermal transport in quantum dots has been extensively studied in the context of steady-state heat engines, e.g. [1]. However, quantum dots are also relevant for cyclic thermal machines as they can be time-dependently driven, e.g. to pump charge. Understanding the characteristics of energy transport in slowly-driven quantum dots is therefore important.
I will present the simple case of a slowly-driven single-level quantum dot weakly coupled to two electronic contacts. The dot has a strong onsite interaction, which can be either repulsive, as typical, or attractive, as realized experimentally, e.g. in [2-4]. I will show the concrete effects of strong many-body interaction and the impact of the interaction sign on energy transport. Then, I will explain how to use this device as a heat pump or refrigerator and highlight the crucial role of the interaction sign in the performances of these thermal machines.
These results [5] were obtained by analyzing adiabatic charge and energy pumping, i.e., transport across the quantum dot due to the slow periodic modulation of system parameters, which is geometric. Our approach uses a fermionic duality for the evolution operator of the master equation [6], which provides compact and insightful analytic expressions. We identified and explained the pumping mechanisms for any pair of driving parameters. Building on this transport analysis, we studied the driven dot as a thermal machine in the presence of a small temperature difference δT between the two contacts. We derived a simple analytical expression of the efficiency in the limit of a vanishing δT which provides an insightful estimate of the device performance. But, even at finite δT and cooling power, we found a sizable efficiency, around 15% of Carnot efficiency. Finally, an attractive interaction yields a lower efficiency than a repulsive one but makes it possible to operate the device with larger δT due to the suppression of stationary currents.

[1] M. Josefsson, A. Svilans, A. M. Burke, E. A. Hoffmann, S. Fahlvik, C. Thelander, M. Leijnse, H. Linke. Nat. Nanotechnol. 13, 920 (2018)
[2] A. Hamo, A. Benyamini, I. Shapir, I. Khivrich, J. Waissman, K. Kaasbjerg, Y. Oreg, F. von Oppen, S. Ilani. Nature 535, 395 (2016)
[3] G. Cheng, M. Tomczyk, A. B. Tacla, H. Lee, S. Lu, J. P. Veazey, M. Huang, P. Irvin, S. Ryu, C.-B. Eom, A. Daley, D. Pekker, J. Levy. Phys. Rev. X 6, 041042 (2016)
[4] G. E. D. K. Prawiroatmodjo, M. Leijnse, F. Trier, Y. Chen, D. V. Christensen, M. von Soosten, N. Pryds, T. S. Jespersen. Nat. Commun. 8, 1 (2017)
[6] J. Schulenborg, R. B. Saptsov, F. Haupt, J. Splettstoesser, M. R. Wegewijs. Phys. Rev. B 93, 081411 (2016)
[5] J. Monsel, J. Schulenborg, T. Baquet, J. Splettstoesser. arXiv:2202.12221

II-28 Julia Boeyens

Position and affiliation: Postgraduate @ University of Siegen
Country: Germany

Title: Continuous measurement feedback for adaptive qubit thermometry

Abstract:
Bayesian estimation was recently applied to quantum thermometry since it allows for better estimation accuracy when data is limited [1] and admits adaptive estimation schemes[2]. Here, we apply the Bayesian framework to the setting of continuous temperature measurement. We model a qubit probe, subject to continuous monitoring interacting with a bosonic bath of unknown temperature. The Kushner-Stratonovich equation from classical filtering theory is simulated to find the posterior distribution. Bayesian estimation is then used to infer the temperature from this probability distribution. This is compared to the discrete analogue, collisional thermometry [3]. An adaptive strategy for improved accuracy is described where Hamiltonian parameters of the qubit can be changed continuously by measurement feedback.

[1] J. Boeyens, S. Seah, S. Nimmrichter; Phys. Rev. A 104, 052214 (2021)
[2] M. Mehboudi et. al.; arXiv:2108.05932 (2021)
[3] S. Seah et. al. Phys. Rev. Lett. 123 180602 (2019)

II-29 Emanuel Schwarzhans
Position and affiliation: Postgraduate @ Institute for Quantum Optics and Quantum Information - IQOQI Vienna, Austrian Academy of Sciences, Boltzmanngasse 3, 1090 Vienna, Austria and Vienna Center for Quantum Science and Technology, Atominstitut, TU Wien, 1020 Vienna, Austria
Country: Austria

Title: The Emergence of Objectivity: Measurement as an equilibration process

Abstract:
Authors: Emanuel Schwarzhans, Felix Binder, Marcus Huber, Maximilian P. E. Lock
Textbook QM allows for two distinct kinds of dynamics of systems: unitary evolution and measurement. Projective measurements are often treated as instantaneous events that prepare a state perfectly in correspondence with the measurement outcome. However, such a treatment of measurement is highly idealized. In fact perfect projective measurements contradict the third law of thermodynamics [1], as they are are unitarily equivalent to cooling a system to its ground state, and thus require an infinite amount of energy or time to be performed [2]. In this work we argue that any measurement must feature an equilibration process, associated with an entropy increase of the apparatus/environment with which the system interacts. We model measurements explicitly as an interaction of the system and its environment, where information of the system (with respect to a preferred basis) gets broadcast throughout the environment [3]. Whenever a measurement is performed, information about the system needs to become redundant and objective (i.e. classical). In other words, multiple observers must be able to agree on the measurement outcome independently. It recently has been shown that states fulfill this requirement if and only if they are of a particular state structure - "spectrum broadcast structure" (SBS) [4,5]. In this work we show the emergence SBS (and thus objectivity) as a result of equilibration. In particular we show how interactions which are conditional on the system state (in the measurement basis) lead to a total environment-system state that is close to the SBS state for most times for a sufficiently large and coarse-grained environment.

[1] Philip Taranto, Faraj Bakhshinezhad, Andreas Bluhm, Ralph Silva, Nicolai Friis, Maximilian P. E. Lock,

Giuseppe Vitagliano, Felix C. Binder, Tiago Debarba, Emanuel Schwarzhans, Fabien Clivaz and Marcus Huber, Landauer vs. Nernst: What is the True Cost of Cooling a Quantum System?, (2021), arXiv:2106.05151
[2] Yelena Guryanova and Nicolai Friis and Marcus Huber, Ideal Projective Measurements Have Infinite Resource Costs, Quantum 4, 222 (2020), 10.22331/q-2020-01-13-222
[3] Wojciech H. Zurek, Quantum Darwinism, Nature Phys 5, 181–188 (2009), 10.1038/nphys1202
[4] R. Horodecki, J. K. Korbicz, and P. Horodecki, Quantum origins of objectivity, Physical Review A 91 (2015), 10.1103/physreva.91.032122
[5] Thao P. Le and Alexandra Olaya-Castro, Strong Quantum Darwinism and Strong Independence are Equivalent to Spectrum Broadcast Structur, Phys. Rev. Lett. 122, 010403, 10.1103/PhysRevLett.122.010403

II-30 Rodolfo Reis Soldati

Position and affiliation: Postgraduate @ University of Stuttgart / University of São Paulo
Country: Germany

Title: Thermodynamics of a minimal algorithmic cooling refrigerator

Abstract:
We investigate, theoretically and experimentally, the thermodynamic performance of a minimal three-qubit heat-bath algorithmic cooling refrigerator. We analytically compute the coefficient of performance, the cooling power and the polarization of the target qubit for an arbitrary number of cycles, taking realistic experimental imperfections into account. We determine their fundamental upper bounds in the ideal reversible limit and show that these values may be experimentally approached using a system of three qubits in a nitrogen-vacancy center in diamond.

II-31 Thomas Hewitt

Position and affiliation: Postgraduate @ University of Birmingham
Country: United Kingdom of Great Britain and Northern Ireland

Title: Ultra-cold Single-atom Quantum Heat Engines

Abstract:
Our experiment is devoted to the study of quantum thermodynamics and aims to realise a single atom quantum heat engine. We take advantage of low-field interspecies Feshbach resonances to control the interactions between an ultracold atomic bath of rubidium-87 and a single potassium-41 atom which is trapped within a species-selective optical tweezer. Engine cycles, including the Carnot, Otto and Diesel engine can then be achieved by the implementation of basic quantum thermodynamic transformations using these tunable interactions.

II-32 Tiago Santos

Position and affiliation: Postgraduate @ Federal University of Rio de Janeiro
Country: Brazil

Title: An optically pumped two-stroke thermal machine

Abstract:
In this work, we study a quantum battery that consists of a qutrit of levels $|g\rangle$, $|i\rangle$ and $|m\rangle$ (from lower to higher energy) connected to a thermal reservoir and to an external work drive. The external drive injects energy in the system coupling levels $|g\rangle$ and $|m\rangle$ and level $|m\rangle$ spontaneously decays into level $|i\rangle$. We focus on the limit in which we can adiabatically eliminate level $|m\rangle$ so that the combination of the external drive and the spontaneous decay optically pumps level $|i\rangle$. We assume that the qutrit is initially in thermal equilibrium with the reservoir (i.e. in a Gibbs state) and the external drive evolves it into a nonequilibrium steady state (NESS) where energy is stored in the system. We analyse the efficiency and the stored power in this pumping process as well as the efficiency and the output power of this quantum battery operating as the work fluid of a two-stroke quantum heat engine. The engine includes a fourth level and operates a cycle where energy is stored through the optical pumping and extracted by means of a unitary transformation. In this scenario, in the discharging stage a second external drive is turned on, extracting the energy stored in the system in the form of work and taking the system into a passive state. Then, in the recharging stage, this second drive is turned off, the optical pumping brings the system back to its active state and restores the working fluid to its initial state. We study this machine in two scenarios: in the ideal case, the discharging stage is isentropic and isochoric in the thermodynamic sense and the machine operates in the limit of short cycles, previously shown in [1, 2]. We also analyse the more general case of longer cycle duration, where there is always heat exchanged between the system and the thermal reservoir and work done on the system.

[1] F. Tacchino, T. F. F. Santos, D. Gerace, M. Campisi, and M. F. Santos, Charging a quantum battery via nonequilibrium heat current, Phys. Rev. E {\bf 102}, 062133 (2020).
[2] Tiago F. F. Santos, Francesco Tacchino, Dario Gerace, Michele Campisi, and Marcelo F. Santos, Maximally efficient quantum thermal machines fueled by nonequilibrium steady states, Phys. Rev A {\bf 103}, 062225 (2021)

II-33 Akram Touil
Position and affiliation: Postgraduate @ UMBC and LANL
Country: United States of America

Title: Quantum Euler relation for local measurements

Abstract:
In classical thermodynamics the Euler relation is an expression for the internal energy as a sum of the products of canonical pairs of extensive and intensive variables. For quantum systems the situation is more intricate, since one has to account for the effects of the measurement back action. To this end, we derive a quantum analog of the Euler relation, which is governed by the information retrieved by local quantum measurements. The validity of the relation is demonstrated for the collective dissipation model, where we find that thermodynamic behavior is exhibited in the weak-coupling regime.

https://www.mdpi.com/1099-4300/23/7/889

II-34 Vasco Cavina
Position and affiliation: Postdoc @ University of Luxembourg
Country: Luxembourg

Title: Maximum power heat engines and refrigerators in the fast-driving regime

Abstract:
We study the optimization of the performance of arbitrary periodically driven thermal machines. Within the assumption of fast modulation of the driving parameters, we derive the optimal cycle that universally maximizes the extracted power of heat engines, the cooling power of refrigerators, and in general any linear combination of the heat currents. We denote this optimal solution as ``generalized Otto cycle'' since it shares the basic structure with the standard Otto cycle, but it is characterized by a greater number of fast strokes. We bound this number in terms of the dimension of the Hilbert space of the system used as working fluid. The generality of these results allows for a widespread range of applications, such as reducing the computational complexity for numerical approaches, or obtaining the explicit form of the optimal protocols when the system-baths interactions are characterized by a single thermalization scale. In this case, we compare the thermodynamic performance of a collection of optimally driven non-interacting and interacting qubits. Remarkably, for refrigerators the non-interacting qubits perform almost as well as the interacting ones, while in the heat engine case there is a many-body advantage both in the maximum power, and in the efficiency at maximum power. Additionally, we illustrate our general results studying the paradigmatic model of a qutrit-based heat engine. Our results strictly hold in the semiclassical case in which no coherence is generated by the driving, and finally we discuss the non-commuting case.
https://doi.org/10.1103/PhysRevA.104.032226

II-35 Dimitris Moustos
Position and affiliation: Postdoc @ University of Patras
Country: Greece

Title: Uniformly accelerated Brownian particle in a bosonic field bath: temperature-dependent dissipation and frequency shift

Abstract:
We consider a harmonic oscillator that is coupled to a massless quantum scalar field, and which is allowed to move along any trajectory in Minkowski spacetime. We employ a quantum Langevin equation to describe the oscillator's dynamics, with the field playing the role of a stochastic force. We investigate a point-like Brownian particle moving with constant acceleration through the Minkowski vacuum and an inertial one immersed in a thermal reservoir at the Unruh temperature. We conclude that although it behaves exactly in the same way in the two scenarios in even spacetime dimensions, this is not the case in odd dimensions. Exploring the consequences of this discrepancy we find that both the accelerated particle's dissipation rate and the shift of its frequency caused by the coupling to the field bath depend on the acceleration temperature. Nonetheless, we show that the fluctuating-dissipation theorem still holds for the particle-field system in the case of odd spacetime dimensions and in the weak-coupling limit an accelerated particle is driven at late times to a thermal equilibrium state at the Unruh temperature.

D. Moustos, arXiv:2201.08287

II-36 Ian Ford

Position and affiliation: Faculty @ UCL
Country: United Kingdom of Great Britain and Northern Ireland

Title: Stochastic entropy production for restricted quantum state diffusion

Abstract:
When the couplings between an open quantum system its environment are insufficiently diverse, the evolution of the reduced density matrix according to the framework of quantum state diffusion will typically be characterised by a diffusion matrix with zero eigenvalues. The implication is that there are directions in the phase space along which motion is deterministic and not stochastic, and this complicates the calculation of the stochastic entropy production of the Brownian motion. Nevertheless, we show that a suitable analysis can separate the dynamical variables that parametrise the density matrix into those that are dissipative in character and contribute to entropy production, and those that are not. We illustrate this with a three-level system driven into a stationary nonequilibrium state.

II-37 Joshua Eglinton

Position and affiliation: Postgraduate @ University of Nottingham
Country: United Kingdom of Great Britain and Northern Ireland

Title: Geometric Bounds on the Power of Adiabatic Thermal Machines

Abstract:
The laws of thermodynamics put fundamental bounds on the efficiencies of thermal machines such as heat engines or refrigerators. However, these Carnot bounds can typically be attained only if the machine is operated quasi-statically, which leads to vanishing power output. How this trade-off between power and efficiency can be captured quantitatively for meso- and micro-scale thermal machines is a question that has attracted significant attention over the last years. Here we use the methods of thermodynamic geometry to analyze the performance of slowly driven meso- and micro-scale devices that operate between two thermal baths with small temperature difference.
Using Onsager's symmetry relations and general scaling argument, we show that the efficiency of such devices reaches the Carnot bound only if heat-leaks between the baths can be fully suppressed. Furthermore, we find that their power is in fact determined by second-order terms in the temperature difference between the two baths, which are neglected in standard linear-response theory. These additional contributions lead to a new family of power-efficiency trade-off relations that imply a quadratic rather than a linear decay of power at Carnot efficiency.
Notably, these relations depend only on geometric quantities such as the thermodynamic length of the driving cycle. Our bounds can be asymptotically saturated in the quasi-static limit if the driving protocols are suitably optimized and the temperature difference between the baths goes to zero with the driving frequency. They hold for essentially any thermodynamically consistent micro-dynamics such as classical Markov-jump processes, adiabatic Lindblad dynamics or coherent transport.
To illustrate our general theory, we investigate two models representing two different classes of systems, a qubit-refrigerator working in a two-stroke cycle and a coherent charge pump operating as cooling devices.

II-38 Matteo Acciai

Position and affiliation: Postdoc @ Chalmers University of Technology
Country: Sweden

Title: Role of fluctuations in a non-equilibrium demon

Abstract:
In recent years, the interest in the thermodynamic properties of small-scale electronic devices has significantly grown, both from a fundamental viewpoint as well as in light of possible applications. For instance, it has been proposed [1] and demonstrated [2] that a 3-terminal system based on quantum dots can act as an efficient energy harvester able to convert waste heat into useful electric power. In this device, heat is absorbed from a hot bath and converted into power allowing an electric current to flow between the remaining two colder reservoirs.
Recent works [3,4] considered the situation where the hot bath – the resource – is replaced by a nonequilibrium distribution and found that useful work can be generated even without absorbing heat (on average) from the resource, thus reminding of a Maxwell-demon behaviour. These systems have been called nonequilibrium demons, both to distinguish them from traditional implementations of Maxwell demons and because they essentially rely on the presence of a nonequilibrium input.
In this presentation, I will show recent results [5] about the role of fluctuations on the performance of a nonequilibrium demon, going beyond a description based on average quantities only. More specifically, we investigate a proposed implementation of a nonequilibrium demon, based on an electronic quantum conductor, by addressing the fluctuations of the (zero-average) charge and heat currents exchanged between the demon and the working substance. We provide a detailed analysis of the influence of fluctuations on the performance of the device, especially focusing on understanding how the input fluctuations affect those of useful output quantities, such as work or cooling power. Furthermore, we also analyse the impact of fluctuations on the efficiency of the device.

[1] A. N. Jordan, B. Sothmann, R. Sánchez, and M. Büttiker; Phys. Rev. B 87, 075312 (2013).
[2] G. Jaliel, et al.; Phys. Rev. Lett. 123, 117701 (2019).
[3] R. S. Whitney, R. Sánchez, F. Haupt, and J. Splettstoesser; Physica E 75, 257 (2016).
[4] R. Sánchez, J. Splettstoesser, and R. S. Whitney; Phys. Rev. Lett. 123, 216801 (2019)
[5] M. Acciai, J. Eriksson, R. Sánchez, R. S. Whitney and J. Splettstoesser (in preparation)

II-39 Philipp Strasberg

Position and affiliation: Postdoc @ Universitat Autonoma de Barcelona
Country: Spain

Title: Everything you wanted to know about the second law (but were afraid to ask)

Abstract:
In this poster I clarify various misconceptions about entropy and the second law dominating the quantum thermodynamics community since many years. I answer questions such as: What is entropy? What is entropy production? What is the second law? What is Clausius' inequality? What is local detailed balance? And how are all these notions interrelated?

II-40 Luis Correa
Position and affiliation: Faculty @ University of Exeter
Country: United Kingdom of Great Britain and Northern Ireland

Title: Breaking the rules of low-temperature thermometry with periodic driving

Abstract:
There exist severe fundamental limitations on thermal sensitivity at low temperatures, which poses a major obstacle for quantum technological applications in the ultracold regime. Low-temperature thermometry can improve substantially by tailoring the interactions between the temperature probe and the sample being measured. In practice, however, the tunability of these dissipative interactions is generally very limited. Here, we focus on a feasible alternative to emulate engineered dissipation—driving the probe. Specifically, we solve for the limit cycle of a periodically modulated harmonic probe dissipatively coupled to an equilibrium sample. Importantly, we do so nonperturbatively in the dissipation strength. We find that weak near-resonant modulation of the trapping potential of the probe can strongly enhance the signal-to-noise ratio of low-temperature measurements with minimal back action on the sample. Our analysis is valid for arbitrarily low temperatures and arbitrary dissipation strengths, and prescribes a simple solution to boost the precision of impurity thermometry on atomic condensates in the nanokelvin range.

II-41 Krzysztof Ptaszyński
Position and affiliation: Postdoc @ Institute of Molecular Physics, Polish Academy of Sciences
Country: Poland

Title: Bounds on skewness and kurtosis of steady state currents

Abstract:
Current fluctuations are a powerful tool to unravel the underlying physics of the observed transport process. This work discusses some general properties of the third and the fourth cumulant of the current (skewness and kurtosis) related to the dynamics and thermodynamics of a system. Specifically, several distinct bounds on these quantities are derived or numerically conjectured, which are applicable to: 1) noninteracting fermionic systems, 2) noninteracting bosonic systems, 3) classical Markovian systems close to equilibrium, 4) unicyclic classical Markovian systems. Finally, it is demonstrated that violation of the obtained bounds can be used to infer the presence of electron pairing in normal metal-superconductor junctions, coherent dynamics and interactions in quantum dot molecules or dynamical channel blockade in multilevel quantum dots even close to equilibrium, when the shot noise - a standard signature of these phenomena - is masked by the thermal noise.

II-42 Nicholas Anto-Sztrikacs
Position and affiliation: Postgraduate @ University of Toronto
Country: Canada

Title: Strong coupling effects in quantum thermodynamics with the reaction coordinate method

Abstract:
At the nanoscale, strong system-reservoir interactions are ubiquitous and could potentially play a large

role in the development of novel nanoscale quantum machines. As a result, a complete formulation of thermodynamics which is valid in the quantum regime must incorporate the effects of strong system-reservoir couplings. The reaction coordinate (RC) mapping is emerging as a significant method in the fields of open quantum systems and quantum thermodynamics, allowing one to go beyond the standard Born-Markov approximation and tackle the strong coupling regime.
I will describe our efforts to apply the RC method to a range of problems in quantum transport and thermodynamics in the strong coupling regime. Such applications range from the investigation of the suppression of thermal current at strong coupling, the emergence of inter-bath transport mechanisms enabled by strong coupling, and finally, the performance of quantum absorption refrigerators where we report a shift in the cooling window in the strong coupling regime relative to weak coupling treatments. Lastly, I will show our efforts to extend the reaction coordinate method to create effective models, where the impacts of strong system-reservoir coupling can be interpreted analytically.

II-43 Naim Elias Comar
Position and affiliation: Postgraduate @ Universidade de São Paulo
Country: Brazil

Title: Correlations break homogenization

Abstract:
The standard collisional model paradigm consists of a system that interacts sequentially with identically prepared ancillas. After infinitely many collisions, and under appropriate conditions, the system may converge to the same state as the ancillas. This process, known as homogenization, is independent of the ancilla initial state, being a property only of the underlying dynamics. In this work we extend this idea to locally identical, but globally correlated, ancillas, and show that correlations break homogenization. This is done numerically using a minimal qubit model, and analytically using an exactly soluble Gaussian model. In both cases, we use Hamiltonian graph states with cyclic graphs as the prototypical method for building scalable many-body entangled ancillary states.

II-44 Tanmoy Biswas
Position and affiliation: Postgraduate @ University of Gdansk
Country: Poland

Title: Fluctuation-dissipation relations for thermodynamic distillation processes

Abstract:
The fluctuation-dissipation theorem is a fundamental result in statistical physics that establishes a connection between the response of a system subject to a perturbation and the fluctuations associated with observables in equilibrium. Here we derive its version within a resource-theoretic framework, where one investigates optimal quantum state transitions under thermodynamic constraints. More precisely, we first characterise optimal thermodynamic distillation processes, and then prove a relation between the amount of free energy dissipated in such processes and the free energy fluctuations of the initial state of the system. Our results apply to initial states given by either asymptotically many identical pure systems or arbitrary number of independent energy-incoherent systems, and allow not only for a state transformation, but also for the change of Hamiltonian. The fluctuation-dissipation relations we derive enable us to find the optimal performance of thermodynamic protocols such as work extraction,

information erasure and thermodynamically-free communication, up to second-order asymptotics in the number N of processed systems. We thus provide a first rigorous analysis of these thermodynamic protocols for quantum states with coherence between different energy eigenstates in the intermediate regime of large but finite N.

II-45 Irene D'Amico

Position and affiliation: Faculty @ University of York
Country: United Kingdom of Great Britain and Northern Ireland

Title: Approximating quantum thermodynamic properties using Density Functional Theory

Abstract:
Authors: K. Zawadzki^1 A. H. Skelt^2, and I. D’Amico^2
1 Department of Physics, Royal Holloway University of London, UK
2 Department of Physics, University of York, UK
The fabrication, utilisation, and efficiency of quantum devices rely on a good understanding of quantum thermodynamic properties. This understanding is crucial for applications’ limits, but also for device fabrication and efficiency. Many-body systems are often proposed as hardware for these quantum devices, but interactions between particles make the complexity of related calculations grow exponentially with the system size. In this respect, while Density Functional Theory (DFT) is one of the most successful methods to
derive properties of complex many-body systems and materials [1], its extension to finite temperature problems, especially for out-of equilibrium systems, is still in its infancy [2]. Here [3], we explore and systematically compare a set of approximations for the average work and entropy variation and which are built on static density functional theory concepts. We divide them in two classes, ‘simple’ and ‘hybrid’. These approximations are computationally cheap and could be applied to large many-body systems. We demonstrate them by considering driven one-dimensional Hubbard chains and show that, for ‘simple’ approximations and low to medium temperatures, it pays to consider a good Kohn-Sham Hamiltonian to approximate the driving Hamiltonian. Our results confirm that a ‘hybrid’ approach, requiring a very good approximation of the initial and, for the entropy, final states of the system, provides great improvements. The ‘hybrid’ approach should be particularly efficient when many-body effects are not increased by the driving Hamiltonian.

[1] “Density functionals and model Hamiltonians: Pillars of many-particle physics” K. Capelle and V. L. Campo, Physics Reports 528, 91 (2013); “Density functional theory: Its origins, rise to prominence, and future” R. O. Jones, Rev. Mod. Phys. 87, 897 (2015)
[2] M. B. Querne and D. Vieira, Brazilian Journal of Physics 49, 615 (2019); J. J. Rehra and J. J. Kas, Eur. Phys. J. B 91 (2018).
[3] Krissia Zawadzki, Amy Skelt, Irene D'Amico, arXiv:2201.05563 (2022)

II-46 Simonov

Position and affiliation: Postdoc @ University of Vienna
Country: Austria

Title: Daemonic ergotropy and non-classical thermalization via quantum switch

Abstract: We characterize the impact that the application of two thermalizing maps in a quantum-controlled order has on the process of work extraction from a qubit via unitary cycles and its optimization. The quantum control of maps is realized within the quantum switch that applies maps in an order not necessarily compatible with the underlying causal structure and, in principle, can be implemented experimentally. We show that although a thermalizing map outputs a completely passive state, thermalization of a qubit with two reservoirs placed in an indefinite causal order via quantum switch allows to activate the qubit's state (and, hence, extract a non-zero ergotropic work) even if it was initially completely passive.

II-47 Archak Purkayastha

Position and affiliation: Postdoc @ Trinity College Dublin
Country: Ireland

Title: Periodically refreshed quantum thermal machines

Abstract:
We introduce a unique class of cyclic quantum thermal machines (QTMs) which can maximize their performance at the finite value of cycle duration τ where they are most irreversible. These QTMs are based on single-stroke thermodynamic cycles realized 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 realization of such processes and show that their implementation requires a finite number of copies of the baths. Interestingly, maximizing performance by operating in the most irreversible point as a function of τ comes at the cost of increasing the complexity of realizing 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).

II-48 Thiago R de Oliveira

Position and affiliation: Faculty @ Universidade Federal Fluminense
Country: Brazil

Title: Nonadiabatic coupled-qubit Otto cycle with bidirectional operation and efficiency gains

Abstract:
We study a quantum Otto cycle that uses a 2-qubit working substance whose Hamiltonian does not commute with itself at different times during the adiabatic strokes. We show this cycle displays regimes of operation with efficiencies higher than the standard Otto one, counter-rotating cycles operating as heat engines and efficiency that can increase with a decrease in the temperature difference between the baths. We also investigate how the cycle responds to variations in the quantum adiabaticity of its unitary strokes, finding it displays an intense response in its efficiency behavior, and significantly changes the

regimes where it operates as an engine.

arXiv preprint arXiv:2201.01664

II-49 Eric Lutz

Position and affiliation: Faculty @ University of Stuttgart
Country: Germany

Title: Experimental study of fully quantum fluctuation theorems using dynamic Bayesian networks

Abstract:
Fluctuation theorems are fundamental extensions of the second law of thermodynamics for small systems. Their general validity arbitrarily far from equilibrium makes them invaluable in nonequilibrium physics. So far, experimental studies of quantum fluctuation relations do not account for quantum correlations and quantum coherence, two essential quantum properties. We here apply a novel dynamic Bayesian network approach to experimentally test detailed and integral fully quantum fluctuation theorems for heat exchange between two quantum-correlated thermal spins-1/2 in a nuclear magnetic resonance setup. We concretely verify individual integral fluctuation relations for quantum correlations and quantum coherence, as well as for the sum of all quantum contributions. We further investigate the thermodynamic cost of creating correlations and coherence.

1) Experimental Validation of Fully Quantum Fluctuation Theorems Using Dynamic Bayesian Networks,
K. Micadei, J.P. S. Peterson, A. M. Souza, R.S. Sarthour, I.S. Oliveira, G.T. Landi, R.M. Serra, and Eric Lutz
Phys. Rev. Lett. 127, 180603 (2021).
2) Quantum Fluctuation Theorems beyond Two-Point Measurements
K. Micadei, G.T. Landi, and Eric Lutz, Phys. Rev. Lett. 124, 090602 (2020).