Workshop
Quantum Thermodynamics of Non-Equilibrium Systems
QTDNEQ20
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organized by DIPC
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There will be prizes for the best two contributed talks and the best two posters.

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Talks and Posters

Invited Talks

1. **Alipour, Sahar** (Aalto University, Helsinki)
   Unreliability of mutual information as a measure for variations in total correlations

2. **Anders, Janel** (University of Exeter)
   Thermodynamic signatures of distinguishability in an optomechanical setting

3. **Auffèves, Alexia** (Institut Néel, Grenoble)
   The energetic cost of work extraction

4. **D’Amico, Irene** (University of York)
   Easy access to energy fluctuations in non-equilibrium quantum many-body systems

5. **del Campo, Adolfo** (DIPC, Bilbao)
   Shortcuts to Adiabaticity in Driven Open Quantum Systems

6. **Haack, Géraldine** (University of Geneva)
   Hybrid Thermal Machines: Generalized Thermodynamic Resources for Multitasking

7. **Kosloff, Ronnie** (Hebrew University, Jerusalem)
   Quantum finite-time thermodynamics: insight from a single qubit engine

8. **Kurchan, Jorge** (LPS Paris)
   Quantum bound to chaos and wave dynamics

9. **Lopez, Rosa** (IFISC, Mallorca)
   Non Linear Chiral refrigerators

10. **Lutz, Eric** (University of Stuttgart)
    Power fluctuations in a finite-time quantum Carnot engine

11. **Pekola, Jukka** (Aalto University, Helsinki)
    Quantum heat transport in superconducting circuits
12. SAMUELSSON, PETER (Lund University)
   Maxwell's demon in a double quantum dot with continuous charge detection

13. SCHMIEDMAYER, JOERG (TU Vienna)
   Quantum Field Thermal Machine

14. SPLETTSTOESSER, JANINE (Chalmers University of Technology, Gothenburg)
   A non-equilibrium system as a demon
Contributed Talks

1. **Abaah, Obinna** (Queen’s University Belfast, UK)
   - Shortcut-to-adiabaticity quantum Otto refrigerator

2. **De Chiara, Gabriele** (Queen’s University Belfast)
   - Quantum thermal machines powered by correlated baths

3. **Guarnieri, Giacomo** (Trinity College Dublin)
   - Quantum fluctuations hinder finite-time information erasure near the Landauer limit

4. **Modi, Kavan** (Monash University)
   - Markovianization with approximate unitary designs

5. **Nation, Charlie** (University College London)
   - From eigenstate thermalization to classical Brownian motion in chaotic quantum systems

6. **Nazir, Ahsan** (University of Manchester)
   - Environmental non-additivity in non-equilibrium quantum systems

7. **Poletti, Dario** (Singapore University of Technology and Design)
   - Giant spin current rectification due to the interplay of negative differential conductance and a non-uniform magnetic field

8. **Sawant, Rahul** (University of Birmingham)
   - Quantum thermodynamics with ultracold atoms

9. **Sayyad, Sharareh** (Néel institut-CNRS)
   - Dynamics of the dissipative Kitaev chain

10. **Strasberg, Philipp** (Universitat Autónoma de Barcelona)
    - Nonequilibrium Entropy & The Second Law

11. **Vasilyev, Denis** (Institute for Quantum Optics and Quantum Information, Innsbruck, Austria)
    - Quantum non-demolition measurement of a many-body Hamiltonian

12. **Verteletsky, Katérina** (Trinity College Dublin)
    - Work and heat in conventional and measurement powered quantum heat engines
Poster Contributions

1. AFSANEH, ELAHEH (University of Isfahan)
   Thermal Revival Entanglement due to Phono assisted process through a carbon-nanotube quantum dot molecule

2. BENABDALLAH, FADWA (Faculty of Sciences, Mohammed V University in Rabat)
   Dynamics of quantum discord based on linear entropy and negativity of qutrit-qubit system under classical dephasing environments

3. BRESQUE, LÉA (Institut Néel)
   A two qubit engine fueled by entanglement and local operations

4. CALAMANCIUC, MADALIN (Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH))
   Evolution of Gaussian quantum discord in a squeezed thermal bath

5. CLOUGHERTY, DENNIS (Department of Physics, University of Vermont, Burlington, VT 05403, USA)
   Infrared Problem in Cold Atom Adsorption on 2D Materials

6. CRESCENTE, ALBA (Universitá degli studi di Genova)
   Charging, energy fluctuations and dissipation of a two-level quantum battery

7. CUZMINSCHI, MARINA (Horia Hulubei National Institute for Physics)
   Steering evolution of a two-mode Gaussian system in the two reservoir model

8. DANN, ROIE (Hebrew University of Jerusalem)
   Quantum finite-time thermodynamics: insight from a single qubit engine

9. DILMI, SAMIA (University of Algeria)
   Superstatistical properties of ionization rates of neutral Helium

10. DUPAYS, LÉONCE (Donostia International Physics Center)
    Fast squeezing and thermalization of a harmonic oscillator
11. **Edet, Collins** (University of Port Harcourt)
   
   **Super-statistical description of thermodynamic properties of diatomic molecules with Deng-Fan-Eckart oscillator.**

12. **Grabarits, András** (Budapest University of Technology and Economics)
   
   **Non-Gaussian work statistics in fermionic nanostructures**

13. **Gubaydullin, Azat** (Aalto University)
   
   **Control of photonic heat transport in superconducting circuits**

14. **Kendon, Viv** (Durham University)
   
   **Collaborative Computational Project – Quantum Computing**

15. **Kiely, Anthony** (University College Dublin)
   
   **Quantum control via Enhanced Shortcuts to Adiabaticity**

16. **Kolář, Michal** (Faculty of Science, Palacký University, Olomouc)
   
   **Enhanced steady-state coherences via repeated system-bath interactions**

17. **Kormos, Márton** (Budapest University of Technology and Economics)
   
   **Theory of quantum work in metallic grains**

18. **Maillet, Olivier** (Aalto University)
   
   **Electric field control of photonic heat transport in a superconducting circuit**

19. **Myers, Nathan** (Department of Physics, University of Maryland, Baltimore, MD 21250, USA)
   
   **Bosons Outperform Fermions: The Thermodynamic Advantage of Symmetry**

20. **Panero, Marco** (University of Turin, INFN, Turin)
   
   **Non-equilibrium thermodynamics equalities for strongly coupled quantum fields**

21. **Purkayastha, Archak** (Trinity College Dublin)
   
   **Tunable phonon-induced steady-state coherence in a double-quantum-dot charge qubit**
22. **ROSSI, LORENZO** (Politecnico di Torino)
   Signature of Generalized Gibbs Ensemble deviation from Equilibrium: Negative absorption induced by a local quench

23. **RUBIO JIMÉNEZ, JESÚS** (University of Exeter)
   Global quantum thermometry

24. **SÁNCHEZ, RAFAEL** (Universidad Autónoma de Madrid)
   Andreev-Coulomb drag in coupled quantum dots

25. **SCALLI, STEFANO** (University of Exeter)
   Local master equations bypass the secular approximation

26. **SHARMA, VAIBHAV** (Cornell University)
   Dissipative Creation of a Topologically Ordered state (AKLT state)

27. **SIMONETTI, SANDRA** (CONICET, UTN, UNS)
   DFT study of amino-functionalized silica for ampicillin adsorption

28. **TOUIL, AKRAM** (University of Maryland Baltimore County)
   Information scrambling vs. decoherence – two competing sinks for entropy

29. **USUI, AYAKA** (Okinawa Institute of Science and Technology Graduate University)
   Simplifying multi-level thermal machines using virtual qubits

30. **YEDJOUR, AFFIFA** (Faculty of Physics, Oran, Algérie)
    Diffusion and localization of cold atoms in Quantum Field Theories

31. **ZUBAREV, ALEXEI** (National Institute for Laser, Plasma and Radiation Physics)
    Optimal quantum teleportation through a Gaussian noisy channel
Invited Talks

Unreliability of mutual information as a measure for variations in total correlations

Sahar Alipour
Aalto University, Helsinki

Correlations disguised in various forms underlie a host of important phenomena in classical and quantum systems, such as information and energy exchanges. The quantum mutual information and the norm of the correlation matrix are both considered as proper measures of total correlations. We demonstrate that, when applied to the same system, these two measures can actually show significantly different behavior except at least in two limiting cases: when there are no correlations and when there is maximal quantum entanglement. We further quantify the discrepancy by providing analytic formulas for time derivatives of the measures for an interacting bipartite system evolving unitarily. We argue that to properly account for correlations one should consider the full information provided by the correlation matrix (and reduced states of the subsystems). Scalar quantities such as the norm of the correlation matrix or the quantum mutual information can only capture a part of the complex features of correlations. As a concrete example, we show that in describing heat exchange associated with correlations neither of these quantities can fully capture the underlying physics. As a byproduct, we also prove an area law for quantum mutual information in systems with local and short-range interactions, without need to assume Markovianity or final thermal equilibrium.
Thermodynamic signatures of distinguishability in an optomechanical setting

JANET ANDERS
University of Exeter

Pioneering thermodynamic thought experiments, such as Maxwell’s demon, Feynman’s ratchet and the mixing of distinguishable or indistinguishable gases discussed by Gibbs, have proven key in the development of statistical physics as well as quantum theory. Here we propose optomechanical setups, involving a cavity in which a membrane is inserted, as a suitable platform to generalise such thought experiments to the quantum regime, with experimental realisations expected to become feasible in the near future. By explicitly modelling two photon gases, distinguished by their polarisation, we show how this setting may be used to probe quantum thermodynamic signatures of distinguishability [1].

To illustrate the setup, we first present a thought experiment in which the energy transfer from two photonic gases to a piston membrane grows quadratically with the number of photons for indistinguishable gases, while linearly for distinguishable gases. We demonstrate that this energetic footprint arises due to Bosonic bunching, an effect that does not occur in classical thermodynamics [1]. Finally, we discuss work extraction from mixing partially distinguishable photon gases [2], where the semipermeable wall proposed by Gibbs for classical gases, is played by a polarising beamsplitter for the photonic gases in the optomechanical setup.

The energetic cost of work extraction

Alexia Auffeves

Institut Néel, Grenoble

We analyze work extraction from a qubit into a waveguide (WG) acting as a battery, where work is the coherent component of the energy radiated by the qubit. The process is stimulated by a wave packet whose mean photon number (the battery’s charge) can be adjusted. We show that the extracted work is bounded by the qubit’s ergotropy, and that the bound is saturated for a large enough battery’s charge. If this charge is small, work can still be extracted. Its amount is controlled by the quantum coherence initially injected in the qubit’s state, that appears as a key parameter when energetic resources are limited. This new and autonomous scenario for the study of quantum batteries can be implemented with state-of-the-art artificial qubits coupled to WGs.
Energy fluctuations play a significant role on the out-of-equilibrium thermodynamics of quantum systems. They are inherently related to fluctuation relations, which embraces both thermal and quantum energy fluctuations. The experimental verification or use of quantum fluctuation relations requires the assessment of both types of energy fluctuations.

Here we combine theoretical and experimental efforts to provide a new powerful method to experimentally access energy fluctuations of a many-body system in an out-of-equilibrium quantum evolution. In particular, inspired by the basic principles behind density functional theory, we show how to obtain the related bi-stochastic matrix of transition probabilities by means of simple local measurements at the end of a protocol that drives a many-body quantum system out-of-equilibrium. This scheme is integrated with numerical optimizations in order to ensure a proper analysis of the experimental data, leading to physical probabilities. The method is experimentally evaluated employing a system of two interacting spin-1/2 in a nuclear magnetic resonance setup. The recovered transition probabilities enable an experimental verification of the detailed fluctuation theorem in a many-body system driven out-of-equilibrium.
Shortcuts to Adiabaticity in Driven Open Quantum Systems

ADOLFO DEL CAMPO

DIPC, Bilbao

A universal scheme is introduced to speed up the dynamics of a driven open quantum system along a prescribed trajectory of interest. This framework generalizes counterdiabatic driving to open quantum processes. Shortcuts to adiabaticity designed in this fashion can be implemented in two alternative physical scenarios: one is characterized by the presence of balanced gain and loss, the other involves non-Markovian dynamics with time-dependent Lindblad operators. As an illustration, we engineer superadiabatic cooling, heating, and isothermal strokes for a two-level system and provide a protocol for the fast thermalization of a quantum oscillator.
Hybrid Thermal Machines: Generalized Thermodynamic Resources for Multitasking

GÉRALDINE HAACK
University of Geneva

Thermal machines perform useful tasks—such as producing work, cooling, or heating—by exchanging energy, and possibly additional conserved quantities such as particles, with reservoirs. Here we consider thermal machines that perform more than one useful task simultaneously, terming these hybrid thermal machines. We outline their restrictions imposed by the laws of thermodynamics and we quantify their performance in terms of efficiencies. To illustrate their full potential, reservoirs that feature multiple conserved quantities, described by generalized Gibbs ensembles, are considered. A minimal model for a hybrid thermal machine is introduced, featuring three reservoirs and two conserved quantities, e.g., energy and particle number. This model can be readily implemented in a thermoelectric setup based on quantum dots, and hybrid regimes are accessible considering realistic parameters.

Reference:
Quantum finite-time thermodynamics: insight from a single qubit engine

Roie Dann, Ronnie Kosloff, Peter Salamon

Hebrew University, Jerusalem

Incorporating time into thermodynamics allows addressing the tradeoff between efficiency and power. A qubit engine serves as a toy model to study this tradeoff from first principles, based on the quantum theory of open systems. We study the quantum origin of irreversibility, originating from heat transport, quantum friction and thermalization in the presence of external driving. We construct various finite-time engine cycles based on the Otto and Carnot templates. Our analysis highlights the role of coherence and the quantum origin of entropy production.
Quantum bound to chaos and wave dynamics

Jorge Kurchan

LPS Paris

The quantum bound to chaos is a limit placed on the low-temperature chaoticity properties imposed by quantum fluctuations. It has its origin in the Black Hole literature, but the physics behind it is easy to understand in terms of the wave nature of quantum mechanics. I will make an elementary review of this.
Non Linear Chiral refrigerators

David Sànchez, Rafael Sànchez, Rosa Lòpez, Bjoern Sothmann

IFISC, Mallorca

We investigate a mesoscopic refrigerator based on chiral quantum Hall edge channels. We discuss a threeterminal cooling device in which charge transport occurs only between a pair of voltage-biased terminals. The third terminal, which is to be cooled, is set as a voltage probe with vanishing particle flux. This largely prevents the generation of direct Joule heating, which ensures a high coefficient of performance. Cooling operation is based on energy-dependent quantum transmissions. The latter are implemented with the aid of two tunable scattering resonances (quantum dots). To find the optimal performance point and the largest temperature difference created with our refrigerator, it is crucial to address the nonlinear regime of transport, accounting for electron-electron interaction effects. Our numerical simulations show that the maximal cooling power can be tuned with the quantum dot couplings and energy levels. Further, we provide analytical expressions within a weakly nonlinear scattering-matrix formalism which allow us to discuss the conditions for optimal cooling in terms of generalized thermopowers. Our results are important for the assessment of chiral conductors as promising candidates for efficient quantum refrigerators with low dissipation.
Power fluctuations in a finite-time quantum Carnot engine

ERIC LUTZ

University of Stuttgart

Stability is an important property of small thermal machines with fluctuating power output. We here consider a finite-time quantum Carnot engine based on a degenerate multilevel system and study the influence of its finite Hilbert space structure on its stability. We optimize in particular its relative work fluctuations with respect to level degeneracy and level number. We find that its optimal performance may surpass those of nondegenerate two-level engines or harmonic oscillator motors. Our results show how to realize high-performance, high-stability cyclic quantum heat engines.
Quantum heat transport in superconducting circuits

Jukka Pekola

Aalto University, Helsinki

I discuss our experiments on quantized heat transport by microwave photons, quantum heat valve and quantum heat rectifier and I present progress on quantum thermodynamics experiments based on ultrasensitive nanocalorimetry.

References on our papers related to this talk:


Maxwell’s demon in a double quantum dot with continuous charge detection

Peter Samuelsson
Lund University

Converting information into work has during the last decade gained renewed interest as it gives insight into the relation between information theory and thermodynamics. Here we theoretically investigate an implementation of Maxwell’s demon in a double quantum dot and demonstrate how heat can be converted into work using only information [1]. This is accomplished by continuously monitoring the charge state of the quantum dots and transferring electrons against a voltage bias using a feedback scheme. We investigate the electrical work produced by the demon and find a non-Gaussian work distribution. To illustrate the effect of a realistic charge detection scheme, we develop a model taking into account noise as well as a finite delay time, and show that an experimental realization is feasible with present day technology. Depending on the accuracy of the measurement, the system is operated as an implementation of Maxwell’s demon or a single-electron pump. As an extension of our model we also discuss how the continuous measurement and feedback can be directly incorporated in a master equation formulation.

Quantum Field Thermal Machine

JOERG SCHMIEDMAYER

TU Vienna

We introduce a blueprint and first experimental steps towards building quantum machines in the framework of the quantum field theory description of complex many body systems [1]. We provide a detailed proposal [2] how to realise a quantum machine in one-dimensional ultra-cold atomic gases using a set of modular operations giving rise to a piston that can be coupled sequentially to thermal baths with the innovation that a quantum field takes up the role of the working fluid. We study the operational primitives numerically in the Tomonaga-Luttinger liquid framework proposing how to model the compression of the system during strokes of a piston and the coupling to a bath giving rise to a valve controlling phononic heat flow. By composing the numerically modeled operational primitives we design complete quantum thermodynamic cycles that are shown to enable cooling and hence giving rise to a quantum field refrigerator. We describe the consequences of operating the machine at the quantum level and give an outlook of how this work serves as a road map to explore open questions in quantum information, quantum thermodynamics and the study of non-Markovian quantum dynamics.


A non-equilibrium system as a demon

Janine Splettstoesser

Chalmers University of Technology, Gothenburg

Maxwell demons are creatures that are imagined to be able to reduce the entropy of a system without performing any work on it. Conventionally, such a Maxwell demon’s intricate action consists of measuring individual particles and subsequently performing feedback. In this talk, I will show that already much simpler setups can act as demons: we have recently demonstrated [1] that it is sufficient to exploit a non-equilibrium distribution to seemingly break the second law of thermodynamics. In this case, neither detection nor feedback on single particles needs to be performed. In contrast, we study a steady-state multi-terminal system, in which a terminal with a non-thermal distribution is used for power production or cooling in a working substance. No overall energy- or particle currents need to flow from the resource to the working substance. This effect is on one hand of fundamental interest due to its apparently paradoxical nature, but can on the other hand also be of interest for applications, in which non-thermal distributions result as “waste” from the operation of a device. We have proposed both electronic and optical implementations of this phenomenon, realizable with current technology [1,2]. In order to quantify the performance of these devices, we propose different types of efficiencies. These compare power production or cooling power in the working substance to the free energy of the resource [3]. Also a comparison of entropy production and reduction in the different device parts turns out to be insightful [3].


Contributed Talks

**Shortcut-to-adiabaticity quantum Otto refrigerator**

**Obinna Abah**

*Queen’s University Belfast, UK*

We investigate the performance of a quantum Otto refrigerator operating in finite time and exploiting local counterdiabatic techniques. We evaluate its coefficient of performance and cooling power when the working medium consists of a quantum harmonic oscillator with a time-dependent frequency. We find that the quantum refrigerator outperforms its conventional counterpart, except for very short cycle times, even when the driving cost of the local counterdiabatic driving is included. We moreover derive upper bounds on the performance of the thermal machine based on quantum speed limits and show that they are tighter than the second law of thermodynamics.
Quantum thermal machines powered by correlated baths

Gabriele De Chiara

Queen’s University Belfast

We consider thermal machines powered by locally equilibrium reservoirs that share classical or quantum correlations. The reservoirs are modelled by the so-called collisional model or repeated interactions model. In our framework, two reservoir particles, initially prepared in a thermal state, are correlated through a unitary transformation and afterwards interact locally with the two quantum subsystems which form the working fluid. For a particular class of unitaries, we show how the transformation applied to the reservoir particles affects the amount of heat transferred and the work produced. We then compute the distribution of heat and work when the unitary is chosen randomly, proving that the total swap transformation is the optimal one. Finally, we analyse the performance of the machines in terms of classical and quantum correlations established among the microscopic constituents of the machine.

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

Kavan Modi
Monash University

Memoryless processes are ubiquitous in nature. However, open systems theory states that non-Markovian processes should be the norm. Here, without resorting to the Born-Markov assumption of weak coupling, we formally prove that physical (non-Markovian) processes look as if they were Markovian. Formally, we show that when a quantum process has the form of an approximate unitary design, a large deviation bound on the size of non-Markovian memory is implied. We exemplify our result making use of efficient construction of an approximate unitary design with an n-qubit quantum circuit using two-qubit interactions only, showing how seemingly simple systems can speedily become forgetful, i.e., they Markovianize. In such cases, detecting the underlying non-Markovian memory would usually require highly entangling resources and hence be a difficult task.
From eigenstate thermalization to classical Brownian motion in chaotic quantum systems

Charlie Nation
University College London

The question of how statistical physics can be seen to emerge from the dynamics of closed quantum systems has seen renewed interest in recent years, driven largely by experimental advancements that have made observations of quantum dynamics over large timescales possible in the laboratory. This talk will focus on how a theoretical framework of quantum chaos may be exploited to describe equilibration dynamics of closed quantum systems from an initial far-from-equilibrium state. Additionally, we will see that a fluctuation-dissipation theorem of classical Brownian motion may be derived under certain physical conditions, and can be shown as a property of individual chaotic eigenstates. Further, upon the introduction of repeated quantum measurements, the average non-equilibrium dynamics of the resulting quantum jump trajectories can be shown to be independent to the presence of such measurements. This enables links to topics of stochastic thermodynamics, for example, by describing the non-decreasing nature of local entropy in closed quantum systems.
Environmental non-additivity in non-equilibrium quantum systems

Ahsan Nazir
University of Manchester

We consider quantum systems coupled simultaneously to multiple environments. Examples include solid-state photon emitters, with coupling both to vibrations and the electromagnetic field, and molecular nanojunctions, with coupling both to vibrations and electronic leads. We show that enforcing additivity of such combined influences results in non-equilibrium dynamics that does not respect the Franck-Condon principle in the former case, and can lead to unphysical electronic current under equilibrium conditions in the latter. We overcome these shortcomings by employing a collective coordinate representation of the vibrational environment, which permits the derivation of a non-additive master equation. When applied to a two-level emitter our treatment predicts a non-equilibrium steady-state with pronounced population inversion. Applied to a thermoelectric molecular nanojunction, we employ counting statistics to track electron flow between the system and the electronic leads, revealing both strong-coupling and non-additive effects in the electron current, noise and Fano factor.
Giant spin current rectification due to the interplay of negative differential conductance and a non-uniform magnetic field

DARIO POLETTI

Singapore University of Technology and Design

In XXZ chains, spin transport can be significantly suppressed when the interactions in the chain and the bias of the dissipative driving are large enough. This phenomenon of negative differential conductance is caused by the formation of two oppositely polarized ferromagnetic domains at the edges of the chain. Here we show that this many-body effect, combined with a non-uniform magnetic field, can allow a high degree of control of the spin current. In particular, by studying all the possible shapes of local magnetic fields potentials, we found that a configuration in which the magnetic field points up for half of the chain and down for the other half, can result in giant spin-current rectification, for example up to $10^8$ for a system with 8 spins. Our results show clear indications that the rectification can increase with the system size.
Quantum thermodynamics with ultracold atoms

RAHUL SAWANT

University of Birmingham

Understanding thermodynamics at the quantum level is one of the big challenges in the field of physics. Ultracold atoms are a promising platform to tackle this challenge as they allow a high degree of control over their internal and external states and to prepare samples with controlled interactions with the environment. Hence, the quantum properties of these systems can be easily controlled and studied.

We have recently built a machine that cools and traps samples of ultracold Rubidium and Potassium atoms for the study of thermodynamics in the quantum regime. One of our major goals is to demonstrate the working of ultracold single-atom quantum heat engines. Recently, we proposed a scheme for building a single atom quantum heat engine based on ultracold atom technologies. In this proposal, we show that the three paradigmatic heat engines, Carnot, Otto, and Diesel are within reach of state-of-the-art technology, and their performances can be benchmarked experimentally. We also consider the use of superadiabatic transformations that allow us to extract a finite amount of power keeping maximum (real) efficiency, and consider the energetic cost of running such protocols. We will discuss how we wish to implement these engines in our experiment and we will report on the experimental progress. Some preliminary experiments will also be discussed.

We will also present the results of a related experiment with the same machine, where we realize a method to produce non-equilibrium Bose-Einstein condensates with purities that cannot be reached by equilibrium samples with the same parameters. To do this, we immerse an ultracold Bose gas of $^{87}$Rb in a cloud of $^{39}$K with substantially higher temperatures, providing a controlled source of dissipation. We demonstrate that our out-of-equilibrium samples are long-lived and do not reach equilibrium in a time that is accessible for our experiment. A controlled dissipative environment is therefore a promising tool for the engineering of systems thermodynamically out of equilibrium.
Dynamics of the dissipative Kitaev chain

Sharareh Sayyad

Néel institut-CNRS

We theoretically investigate the non-Hermitian dynamical topology of a driven-dissipative Kitaev chain. For this, we have employed the third quantization formalism [1] to explore signatures of the non-trivial topology in the time-evolution of the entanglement spectra.

We shall first present a concise summary of the underlying physics of the Kitaev chain and clarify the merits of stepping outside the realm of Hermitian physics. We then focus on the driven-dissipative Kitaev chain and explore its richer phase diagram with gapless, real-line gapped, imaginary-line gapped, and topological phases.

We further discuss this system’s dynamics from the initial dissipationless trivial phase to other regions of the phase diagram. We reveal that non-trivial topology is reflected in crossings in the entanglement spectrum for quenches from a trivial to the topological phase. We shall also describe the non-Hermitian classification of our systems using a generalized winding number. Finally, we shall emphasize that our results are unique to interacting quantum systems. This work has been done in collaboration with Jinlong Yu, Adolfo Grushin, and Lukas Sieberer.

Nonequilibrium Entropy & The Second Law

PHILIPP STRASBERG

Universitat Autònoma de Barcelona

The second law asserts that the thermodynamic entropy in the universe increases. To derive this statement microscopically, it is necessary to start first of all with a definition of thermodynamic entropy for the universe, valid in and out of equilibrium. Surprisingly, this question was not yet investigated within the context of quantum thermodynamics. In this talk I will propose one definition, which is known as observational entropy. This definition fulfills a second law and a fluctuation theorem. In contrast to previous approaches, the present approach is not only conceptually more satisfying, but also very flexible. It allows to treat within the same formalism the cases of one or multiple baths of any size, baths initially prepared in a large class of states (beyond the conventional Gibbs state paradigm) and possibly initially correlated with the system.
Quantum non-demolition measurement of a many-body Hamiltonian

DENIS VASILYEV

Institute for Quantum Optics and Quantum Information, Innsbruck, Austria

In an ideal quantum measurement, the wave function of a quantum system collapses to an eigenstate of the measured observable, and the corresponding eigenvalue determines the measurement outcome. If the observable commutes with the system Hamiltonian, repeated measurements yield the same result and thus minimally disturb the system. Seminal quantum optics experiments have achieved such quantum non-demolition (QND) measurements of systems with few degrees of freedom. In contrast, here we describe how the QND measurement of a complex many-body observable, the Hamiltonian of an interacting many-body system, can be implemented in a trapped-ion or Rydberg tweezer based analog quantum simulator. Through a single-shot measurement, the many-body system is prepared in a narrow band of (highly excited) energy eigenstates, and potentially even a single eigenstate. Our QND scheme, which can be carried over to other platforms of quantum simulation, provides a framework to investigate experimentally fundamental aspects of equilibrium and non-equilibrium statistical physics including the eigenstate thermalization hypothesis and quantum fluctuation relations.
We constructed a simple autonomous thermoelectric engine operated out of thermal equilibrium composed of two superconducting qubits coupled to separate heat baths and connected by a Josephson junction. By deriving analytical expressions for the Hamiltonian and steady-state solution of the master equation, we studied the dynamics of the machine. We showed that, for this system, the fluctuations in the integrated work and heat over finite time intervals are not simply the variances of suitable system observables but employ more complex quantum correlation functions. In particular, the transfer of heat into the cold bath is equivalent to the process of spontaneous emission from a quantum light source, and its temporal correlations thus follow from Glauber’s photodetection theory in quantum optics. In addition, by investigating the conditional dynamics of the excitation propagating through the system by way of two-time correlation functions, we revealed a cyclical, dynamical transfer of energy mimicking the chuffing of a classical steam engine. Finally, we went beyond the conventional engine design and considered a machine where the heat baths were replaced by a measurement protocol. By deriving and analyzing the periodic steady state of our machine, we showed that for such a design, an adaptive measurement scheme allows a net work production on average. These results offer an interesting basis for experimental implementation, especially in cases where the size of the device does not permit an efficient separation between the heat baths.
Posters

1. Thermal Revival Entanglement due to Phono assisted process through a carbon-nanotube quantum dot molecule

Elaheh Afsaneh
University of Isfahan

In the present contribution, I investigate the dynamics of entanglement generation in a carbon nanotube quantum dot molecule with the phonon interactions in a bias voltage junction. The generated entanglement between coupled quantum dots can be engineered by employing an asymmetric coupling strategy. This leads to preserving the entanglement with an achievable robust value steadily. In this system, the phenomena of thermal entanglement degradation and revival are observed through the temperature-varying. The quantum thermodynamics of this system shows that the stronger thermal revival entanglement occurs for the larger phonon coupling magnitude. Also, the behavior of entanglement for higher temperatures is demonstrated through the concurrence high-temperature approximation.
2. Dynamics of quantum discord based on linear entropy and negativity of qutrit-qubit system under classical dephasing environments

FADWA BENABDALLAH

Faculty of Sciences, Mohammed V University in Rabat

Quantum entanglement plays important roles in many areas of quantum information processing (QIP). Nevertheless, quantum entanglement is not the only form of quantum correlation that is useful for QIP. In fact, some separable states may also speed up certain quantum tasks, relative to their classical counterparts. An example of such quantum correlation is a quantity, called quantum discord (QD), which can effectively capture all quantum correlations present in various kinds of quantum systems. The quantum discord involves a minimization procedure that is difficult to solve in general. To overcome the difficulty encountered with the computability of quantum discord based on von Neumann entropy, we propose a reliable analytical method to evaluate the quantum discord based on linear entropy for an arbitrary qudit-qubit quantum state. The quantum discord based on linear entropy is employed to derive the dynamics of quantum correlations for a qutrit-qubit system undergoing a global (bilocal + collective) classical dephasing environment. Our studies focus mainly on a particular initial qutrit-qubit state in thermal equilibrium at a temperature $T$. The obtained value of quantum discord (QD) is then compared with the measurement-induced disturbance (MID) and logarithmic negativity (LN). The analysis shows that both QD and MID are more robust than entanglement (LN) against the decoherence effect. Besides, the system exhibits interesting behaviors. As for instance, freezing dynamics and entanglement sudden death (ESD). The method developed in this paper to quantify quantum correlations is reliable because it allows us to consider analytically the arbitrary qutrit-qubit quantum states in the classical dephasing environment.
3. A two qubit engine fueled by entanglement and local operations

Léa Bresque

Institut Néel

We introduce a two-qubit engine that is powered by entangling operations and projective local quantum measurements. Energy is extracted from the detuned qubits coherently exchanging a single excitation. This engine, which uses the information and back-action of the measurement, is generalized to an $N$-qubit chain. We show that by gradually increasing the energy splitting along the chain, the initial low energy of the first qubit can be up-converted deterministically to an arbitrarily high energy at the last qubit by successive neighbor swap operations and local measurements. Modeling the local measurement as the entanglement of a qubit with a meter, we identify the measurement fuel as the energetic cost to erase correlations between the qubits.
4. Evolution of Gaussian quantum discord in a squeezed thermal bath

Madalin Calamanciuc
Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH)

We describe the Markovian dynamics of the Gaussian quantum discord of a system composed of two uncoupled bosonic modes in two cases: when they are in contact with a common squeezed thermal bath, and when each of them is interacting with its own squeezed thermal bath. This study is done in the framework of the theory of open quantum systems, based on completely positive quantum dynamical semigroups. We take an initial squeezed thermal state and we show that the behaviour of the Gaussian quantum discord depends on the bath parameters (temperature, dissipation coefficient, squeezing parameter and squeezing phase), and on the initial state of the system (squeezing parameter and average photon numbers). We show that Gaussian quantum discord is decaying in time, tending asymptotically to zero, due to the effect of the environment. We also compare the Gaussian quantum discord with the Gaussian geometric discord.
5. Infrared Problem in Cold Atom Adsorption on 2D Materials

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There has been some controversy [1] concerning the phonon-assisted adsorption of atomic hydrogen to suspended graphene at low energies, one numerical calculation predicts an enhancement of the adsorption rate in comparison to the rate on graphite [2], while another work has argued for a suppression of adsorption [3]. Recent theoretical results of the adsorption rate of atomic hydrogen to suspended graphene are presented using four different methods that include contributions from processes with multiphonon emission. We compare the numerical results of the atom self-energy obtained by: (1) the loop expansion of the atom self-energy, (2) the non-crossing approximation (NCA) [4], (3) the independent boson model approximation (IBMA) [4], and (4) a leading-order soft-phonon resummation method (SPR) [5].

The loop expansion reveals an infrared problem, analogous to the infamous infrared problem in QED. The 2-loop contribution to the sticking rate gives a result that tends to diverge for large membranes. The latter three methods remedy this infrared problem for a membrane at zero temperature and give results that are finite in the limit of an infinite membrane. At finite temperature, the divergence problems are exacerbated, only SPR gives a finite adsorption rate in the limit of an infinite membrane [6]. For micromembranes (sizes ranging 100 nm to 10 um) at zero temperature, the latter three methods give results that are in good agreement with each other and yield sticking rates that are mildly suppressed relative to the lowest-order golden rule rate. However, the SPR sticking rate decreases to zero with increasing membrane size for all temperatures. Thus, approximations to the sticking rate are sensitive to the effects of soft-phonon emission for large membranes.

6. Charging, energy fluctuations and dissipation of a two-level quantum battery

ALBA CRESCENTE

Università degli studi di Genova

We consider a two-level quantum system driven by an external classical source as the simplest possible building block of a quantum battery. Here we analyze the performance of this device in terms of energy storage, time of charging and energy fluctuations during the charging process.

Using a numerical analysis, we characterize the role of different initial conditions for the system as well as the sensitivity to the functional form of the drive.

Moreover dissipation due to the presence of an environment is considered. In the weak-coupling regime analytical expressions of the stored energy are found. Here we analyze how the interaction with a thermal reservoir affects the dynamics of the quantum battery.

This study aims at providing a solid theoretical background in view of future experimental implementations.


7. Steering evolution of a two-mode Gaussian system in the two reservoir model

MARINA CUZMINSCHI

Horia Hulubei National Institute for Physics

Let us consider a quantum system consisting of two entangled Gaussian modes placed each in its own thermal reservoir. We consider existence of a finite squeezing between modes, coupling between modes is zero and assume that modes are placed in thermal baths with different temperatures. The evolution of this system is a Markovian one and can be described using covariance matrix formalism in the framework of open systems based on completely positive quantum dynamical semigroups. In this work we focus on the study of quantum steering and determine its evolution in time as function of squeezing between modes, temperature of reservoirs, frequencies of the modes and damping. We prove that steering decreases in time and with increase of the reservoirs temperatures and increases with the increase of squeezing between the modes.
8. Quantum finite-time thermodynamics: insight from a single qubit engine

Roie Dann

Hebrew University of Jerusalem

Incorporating time into thermodynamics allows addressing the tradeoff between efficiency and power. A qubit engine serves as a toy model to study this tradeoff from first principles, based on the quantum theory of open systems. We study the quantum origin of irreversibility, originating from heat transport, quantum friction and thermalization in the presence of external driving. We construct various finite-time engine cycles based on the Otto and Carnot templates. Our analysis highlights the role of coherence and the quantum origin of entropy production.
9. Superstatistical properties of ionization rates of neutral Helium

Samia Dilmi

University of Algeria

Electron-impact ionization (EII) can be important in dynamic systems where ions are suddenly exposed to higher electron temperatures. For this reason, EII may be important for studies of solar flares, nanoflare coronal heating, supernova remnants, and merging galaxy clusters. EII can also have a significant effect on the charge state distribution for plasmas with a non-thermal electron energy distribution. For such plasmas there is a substantial population of electrons in the high energy tail of the distribution that lie above the EII threshold. Thus, EII is relevant to the modeling of astrophysical systems where such non-thermal distributions are present. We demonstrate the connection between the Maxwellian distributions and the Beck-Cohen superstatistics and we study the influence of superstatistics on nonthermal and suprathermic distributions on the calculation of ionization rates for neutral helium and Be.
10. Fast squeezing and thermalization of a harmonic oscillator

LÉONCE DUPAYS

Donostia International Physics Center

Control protocols known as shortcuts to adiabaticity allow to drive a quantum system from an initial to a final state arbitrarily fast. These techniques have recently been proposed for open quantum systems, thus extending their application to allow for fast thermalization. Here, we engineer dynamical schemes for the fast preparation of squeezed thermal states at controlled temperature. We derive the equations of motion of squeezed thermal states in harmonic oscillators under unitary and open dynamics, allowing for temperature and entropy variations between the initial and final states. The counter-diabatic Hamiltonians and associated dissipators are provided, and whenever possible, given in a form relevant to experimental application. The technique is detailed in the setting of trapped-ion experiments with two-photon Raman interaction, where the desired open dynamics is obtained from stochastically shaking the trapping potential, or driving the system with a laser of stochastic amplitude. In this context, we find solutions for the control parameters—namely laser amplitude, phase, and dephasing strength—that allow creating a squeezed thermal state at controlled temperature in arbitrary time.

**Collins Edet**

*University of Port Harcourt*

In this study, we carry out a superstatistical analysis of diatomic molecules via Deng-Fan-Eckart Oscillator with the Dirac-delta distribution. The energy equation of the system is first obtained by solving the Schrodinger equation via the exact quantisation rule (EQR) and the numerical eigenvalue compared with literature for validity. With the analytic energy expression and some algebraic manipulations, the partition function is obtained. The partition function is then used to obtain other thermodynamic functions in terms of the deformation parameter $q$. By way of showing application, we extend this concept to the case of diatomic molecules.
12. Non-Gaussian work statistics in fermionic nanostructures

ANDRÁS GRABARITS

Budapest University of Technology and Economics

We investigate the statistical properties of work performed on generic disordered fermionic nanograins under the effect of external fields during non-equilibrium quantum quenches. We construct a simple mean field theory, incorporating only Pauli’s exclusion principle, particle number conservation, and the diffusive character of the occupation numbers, yielding amazingly precise analytic expressions for the distribution of work in the case of zero temperature for arbitrarily fast driven quantum systems. The tail of the work distribution for large work is found to decay exponentially rather than being Gaussian. Using an effective temperature formalism, we obtain an analytic expression for the work statistics for large enough injected works via bosonisation. For quenches at finite temperature we derive an exact determinant formula for the characteristic function of the work statistics. In contrast to the zero temperature case, the work can also take negative values and in the limit of large temperatures it converges to a Gaussian distribution. We find that even at finite temperatures, the average work increases linearly with time. We also verified that for symmetrical cyclic driving our results satisfy the Crooks fluctuation relation at finite temperatures.
13. Control of photonic heat transport in superconducting circuits

AZAT GUBAYDULLIN

Aalto University

We study the fundamental quantum thermodynamics in mesoscopic systems, particularly, we study photonic heat transport in dissipative open quantum systems, realized by integrating the tools of ultrasensitive microwave bolometry with those of superconducting circuits.
14. Collaborative Computational Project – Quantum Computing

Viv Kendon
Durham University

CCP-QC is an EPSRC-funded network linking computational scientists with quantum computing scientists and engineers, to develop some of the first useful applications of quantum computers. An important set of computational tasks in materials, chemistry, physics, biology, and engineering is developed by communities supported by collaborative computational projects (CCPs).

CCP-QC will network across these CCPs and the quantum computing community, to enable the CCP communities to enhance their computations by using quantum computers. It will do this by organising joint meetings, holding training days to teach computational scientists about quantum computing, supporting small projects to develop proof-of-principle code and demonstrations on early quantum computing hardware, and providing an online information resource on early quantum computing applications. This poster will introduce CCPs in general, CCP-QC in particular, and explain how to get involved.
Fast and robust quantum control protocols are often based on an idealized approximate description of the relevant quantum system. While this may provide a performance that is close to optimal, improvements can be made by incorporating elements of the full system representation. We propose a technique for such scenarios, called enhanced shortcuts to adiabaticity (eSTA). The eSTA method works for previously intractable Hamiltonians by providing an analytical correction to existing STA protocols. This correction can be easily calculated, and the resulting protocols are outside the class of STA schemes.
16. Enhanced steady-state coherences via repeated system-bath interactions

Michal Kolář

Faculty of Science, Palacký University, Olomouc

The autonomous appearance of the steady-state coherence (SSC) from system-bath interaction proves that quantum effects can appear without an external drive [1]. Such SSC could become a resource to demonstrate quantum advantage in the applications. We predict [2] the generation of SSC if the target system repeatedly interacts with independent and non-correlated bath elements. To describe the behavior of SSC, we use the collision model approach [3] of system-bath interaction, where the system interacts with one bath element (initially in an incoherent state) at a time, asymptotically (in the fast-collision regime) mimicking a macroscopic Markovian bath coupled to the target system. Therefore, SSC qualitative behavior appears to be the same as if the continuous Markovian bath would be used. We confirm that the presence of composite system-bath interactions under the rotating-wave approximation (RWA) is the necessary condition for the generation of SSC using thermal resources in collision models. Remarkably, we show that SSC substantially increases if the target system interacts collectively with more than one bath element at a time. Already few bath elements collectively interacting with the target system are sufficient to increase SSC at non-zero temperatures, at the cost of tolerable lowering the final state purity.

17. Theory of quantum work in metallic grains

MÁRTON KORMOS
Budapest University of Technology and Economics

We apply a random matrix approach to describe the statistics of work performed on generic disordered, noninteracting fermionic systems during quantum quenches [1]. We generalize and apply Anderson’s orthogonality determinant formula to compute the full distribution of quantum work generated by formations of the Hamiltonian. The energy absorbed increases linearly with time, while its variance exhibits a superdiffusive behavior, reflecting Pauli’s exclusion principle. The probability of adiabatic evolution decays as a stretched exponential. In slowly driven systems, work statistics exhibit universal features and can be understood in terms of fermion diffusion in energy space, generated by Landau-Zener transitions. This diffusion is very well captured by a Markovian symmetrical exclusion process, with the diffusion constant identified as the energy absorption rate. The energy absorption rate shows an anomalous frequency dependence at small energies, reflecting the symmetry class of the underlying Hamiltonian. Our predictions can be experimentally verified by calorimetric measurements performed on nanoscale circuits.

18. Electric field control of photonic heat transport in a superconducting circuit

O. Maillet, D. A. Subero, J. T. Peltonen, D. S. Golubev, and J. P. Pekola

Aalto University

Very few experiments probe quantum heat transport by photons, and all are made difficult by the forbidding use of a magnetic field to control heat flows. Here we present a magnetic field-free circuit where charge quantization in a superconducting island enables thorough electric field control. We thus tune the thermal conductance, close to its quantum limit, of a single photonic channel between two mesoscopic reservoirs. We observe heat flow oscillations originating from the competition between Cooper-pair tunnelling and Coulomb repulsion in the island, well captured by a simple model. Our results highlight the consequences of charge-phase conjugation on heat transport, with promising applications in thermal management of quantum devices and design of microbolometers. In addition, preliminary results indicate that the use of ultrasmall Josephson junctions coupled to high-impedance thermal baths leads to non-trivial thermal conduction mechanisms due to the bath back-acting on the junctions, providing an example of quantum thermal transport in strongly coupled systems.

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The recent miniaturization of heat engines to the nanoscale introduces the possibility of engines that harness quantum resources. The analysis of quantum engines provides important insight into how their efficiency compares to classical analogues and deepens our understanding of thermodynamic mechanisms at the quantum scale. We examine a quantum Otto engine with a harmonic working medium consisting of two particles to explore the use of wave function symmetry as an accessible resource. It is shown that a bosonic working medium displays enhanced performance when compared to distinguishable particles, while a fermionic working medium displays reduced performance. To this end, we explore the trade-off between efficiency and power output and the parameter regimes under which the system functions as engine, refrigerator, or heater. Remarkably, the bosonic system operates under a wider parameter space both when operating as an engine and as a refrigerator.
20. Non-equilibrium thermodynamics equalities for strongly coupled quantum fields

MARCO PANERO

University of Turin, INFN, Turin

I discuss the application of exact non-equilibrium thermodynamics relations to the study of quantum field theory in a non-perturbative regime. I focus on some recent, high-precision results relevant for different problems, including the equation of state of the early Universe, and the evolution of the coupling of the strong nuclear interaction at different energy scales.
21. Tunable phonon-induced steady-state coherence in a double-quantum-dot charge qubit

ARCHAK PURKAYASTHA

Trinity College Dublin

Charge qubits can be created and manipulated in solid-state double-quantum-dot (DQD) platforms. Typically, these systems are strongly affected by quantum noise stemming from coupling to substrate phonons. This is usually assumed to lead to decoherence towards steady states that are diagonal in the energy eigenbasis. Here, we show, to the contrary, that due to the presence of phonons the equilibrium steady state of the DQD charge qubit spontaneously exhibits coherence in the energy eigenbasis with high purity. This is due to the quantum nature of noise generated by the phonons. Our results show that, in general, quantum noise in qubit parameters generate coherence, while classical noise destroys coherence. The magnitude and phase of the coherence can be controlled by tuning the Hamiltonian parameters of the qubit. The coherence is also robust to the presence of fermionic leads. In addition, we show that this steady-state coherence can be used to drive an auxiliary cavity mode coupled to the DQD.
22. Signature of Generalized Gibbs Ensemble deviation from Equilibrium: Negative absorption induced by a local quench

LORENZO ROSSI

Politecnico di Torino

A huge effort is currently devoted to understand the relaxation properties of isolated out-of-equilibrium quantum systems. In presence of integrability there is a growing theoretical consensus that the proper late time statistical description is encoded in a Generalized Gibbs Ensemble (GGE), which is built out of all the conserved observables. However, only a few experimental signatures of such behavior have been observed, and are mostly limited to Bose gases. In our work we propose a conceptually simple and realistic protocol to observe, through optical measurements, the effects of a GGE pre-thermalization in a one-dimensional (1D) fermionic system: we rigorously show that, by quenching a suitable local external potential in a 1D free Fermi gas, the post-quench system is characterized by a partially occupied bound state lying below a continuum of fully occupied states. Such striking population inversion induces a negative peak in the absorption spectrum, i.e. a stimulated emission of radiation in a well defined frequency range. This result could thus pave the way to the observation of GGE fingerprints through optical measurements in fermionic systems.
23. Global quantum thermometry

Jesús Rubio Jiménez

University of Exeter

Protocols to measure temperature accurately are essential to understand the physics that governs the mesoscopic scale, and quantum thermometry provides the tools to achieve this goal in the quantum domain. However, the current formalism is only applicable in a local sense. This implies that, in general, one can only exploit the precision enhancements predicted by the theory when either the temperature is known to lie within a very narrow interval, or our thermometer is built out of an asymptotically large system, or perhaps both. To go beyond these important limitations, in this work we present the foundations of global quantum thermometry, a new theory that is applicable to finite-size thermometers and can accommodate larger temperature intervals. By considering a fermionic system, we will demonstrate that, while our approach recovers the local theory as a limiting case, it does predict different optimal estimates when the thermometer operates in the global regime. We will conclude by discussing the potential of our framework to design realistic quantum thermometers using small thermodynamic systems.
24. Andreev-Coulomb drag in coupled quantum dots

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Universidad Autónoma de Madrid

Electrical power can be generated in a quantum dot system that rectifies the energy absorbed from non-equilibrium fluctuations of its environment. Typically, this depends on tiny energy-dependent asymmetries of the device [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. The non-equilibrium charge fluctuations in the second dot correlate with the Andreev processes that inject Cooper pairs in the superconductor. This provides the necessary symmetry breaking energy transfer. We analyze this mechanism in two configurations depending on the non-equilibrium source: i.e., when the quantum dot is coupled to (i) two terminals at different chemical potential, and (ii) a single but hot terminal. We show that pair and quasiparticle contributions can be distinguished by a change of sign of the generated current. The investigation of the injected heat current provides additional insights and enable the definition of gate-tunable heat engines based on quantum many-body correlations.

25. Local master equations bypass the secular approximation

Stefano Scali
University of Exeter

Master equations are a vital tool to model heat flow through nanoscale thermodynamic systems. Most practical devices are made up of interacting sub-system, and are often modelled using either local master equations (LMEs) or global master equations (GMEs). While the limiting cases in which either the LME or the GME breaks down are well understood, there exists a "grey area" in which both equations capture steady-state heat currents reliably, but predict very different transient heat flows. In such cases, which one should we trust? Here, we show that, when it comes to dynamics, the local approach can be more reliable than the global one for weakly interacting open quantum systems. This is due to the fact that the secular approximation, which underpins the GME, can destroy key dynamical features. To illustrate this, we consider a minimal transport setup and show that its LME displays exceptional points (EPs). These singularities have been observed in a superconducting-circuit realisation of the model. However, in stark contrast to experimental evidence, no EPs appear within the global approach. We then show that the EPs are a feature built into the Redfield equation, which is more accurate than the LME and the GME. Finally, we show that the local approach emerges as the weak-interaction limit of the Redfield equation, and that it entirely avoids the secular approximation.
26. Dissipative Creation of a Topologically Ordered state (AKLT state)

VAIBHAV SHARMA

Cornell University

Dissipation of a quantum system coupled to an environment often destroys a quantum state of interest, but if carefully engineered, it can be used as a tool to prepare interesting quantum states. We propose an experimentally viable method to dissipatively create the AKLT (Affleck-Lieb-Kennedy-Tasaki) state which exhibits symmetry protected topological order. We analyze a system of lattice bosons, which are constrained to move in a one dimensional tilted optical lattice and couple them to a bosonic superfluid bath. We use a coherent raman beam to drive rabi oscillations of atoms between nearest neighbor sites and lowest two motional bands. We use a lindblad master equation approach to model this driven-dissipative process and determine that the engineered driven-dissipative process has a steady state which is the AKLT state. We also calculate the state preparation time scales with system size, bath density and mass of the bath atoms.
27. DFT study of amino-functionalized silica for ampicillin adsorption

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CONICET, UTN, UNS

Nanocarriers to transport substances are hopeful places to increase the beneficial treatment of medical drugs. Ampicillin is an extensive-spectrum penicillin derivative used to treat several diseases and infections. Due to its great utility and small cost, ampicillin can be a model for a better analysis of the adsorption processes of drugs in novel ceramic materials such as functionalized silica. The adsorption of ampicillin drug on SiO2(001) and SiO2(111) hydroxylated surfaces have been studied by DFT calculations that have become an important tool to understand the behavior of materials. In this work, the improvement on adsorption when the system is functionalized with amino groups, are analyzed. The changes on adsorption of the pH dependence-ampicillin species are studied. Ampicillin molecule approaches on both surfaces via N and O atoms, doing more stable on SiO2(001). The stability depends on the H-bonds formed and this is conformity with the higher silanol density of SiO2(001) surface. The stability of ampicillin on SiO2(111) is favored when the surface is amino functionalized and the major adsorption energy is observed in presence of the deprotonated specie at basic pH. The changes are mainly related to the modification on HOMO-LUMO distribution comparing with the neutral specie and in consequence, the new interactions with the amino functionalized surface that contribute with new states in the DOS Fermi region.
A possible solution of the information paradox can be sought in quantum information scrambling. In this paradigm, it is postulated that all information entering a black hole is rapidly and chaotically distributed across the event horizon making it impossible to reconstruct the information by means of any local measurement. However, in this scenario the effects of decoherence are typically ignored, which may render information scrambling moot in cosmological settings. In this work, we develop key steps towards a thermodynamic description of information scrambling in open quantum systems. In particular, we separate the entropy production into contributions arising from scrambling and decoherence, for which we derive statements of the second law. This is complemented with a numerical study of the Sachdev-Ye-Kitaev, Maldacena-Qi, XXX, mixed field Ising, Lipkin-Meshkov-Glick models in the presence of decoherence in energy or computational basis.
29. Simplifying multi-level thermal machines using virtual qubits

Ayaka Usui

Okinawa Institute of Science and Technology Graduate University

Quantum thermodynamics often deals with the dynamics of small quantum machines interfacing with a large and complex environment. Virtual qubits, collisional models and reset master equations have become highly useful tools for predicting the qualitative behaviour of two dimensional target systems coupling to few-qubit machines and a thermal environment. While matching the simplified model parameters for all possible physical systems is an impossibly hard task in general, the qualitative predictions still allow for a general design of quantum machines irrespective of the implementation. We generalise these tools by introducing multiple competing virtual qubits for modelling multi-dimensional systems coupled to larger and more complex machines. By simulating the full physical dynamics for targets with three dimensions, we uncover general properties of the reset models that can be used as “knobs” to correctly predict the qualitative features of physical changes in a realistic setup and thus design autonomous quantum machines beyond a few qubits. We then present a general analytic solution of the reset model for arbitrary dimensional systems couple to multi-qubit machines.
30. Diffusion and localization of cold atoms in Quantum Field Theories

Afifa Yedjour

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The nature of the spectrum obtained from light waves in the presence of a random potential is an effective means of acquiring information on the medium. Reflection and transmission mode imaging and non-destructive testing are widely used in medical and industrial applications, which provide comfortable signal power. In this context, we will examine the behavior of the transmission coefficient over time by considering the one-dimensional mesoscopic systems of Aubry-André. We study a wave described by the one-dimensional Schrödinger equation to calculate $T(E)$ for a statistical set of 103 samples which differ only in the realization of the disorder $V(n)$. We found that $T(E)$ decrease of $1/t^{0.76}$ when $E = 0.5$ and a fraction of a particle is localized. We conclude that for lower long-term, the contribution should algebraically decay more slowly until $\langle T \rangle$ disappears. This result close with the literature where the authors found that in particular, the probability for a particle to move to a given lattice site after a long time decreases very slowly as $(P(t) t^{0.14})$ to arbitrary disorder $W$.

31. Optimal quantum teleportation through a Gaussian noisy channel

ALEXEI ZUBAREV

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In this work we study quantum teleportation of a pure coherent state using through a noisy channel, in order to find optimal systems parameters requested for a successful teleportation. As the resource for teleportation is proposed a two-mode Gaussian state placed in a contact with a squeezed thermal environment. To describe the teleportation processes and resources state evolution we work in the framework of the theory of open systems based on completely positive quantum dynamical semigroups. We explore the Markovian dynamics of the fidelity of teleportation and logarithmic negativity, which are investigated in terms of the covariance matrix of the considered system. Both the fidelity of teleportation and the presence of the entanglement in the system are correlated to the chosen parameters of the initial resource state and the squeezed thermal bath. As well we determine entanglement survival time and maximal allowed time of teleportation.
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