Third Working Group Meeting of the

COST Action MP1209

Belfast, 18-20 August 2014

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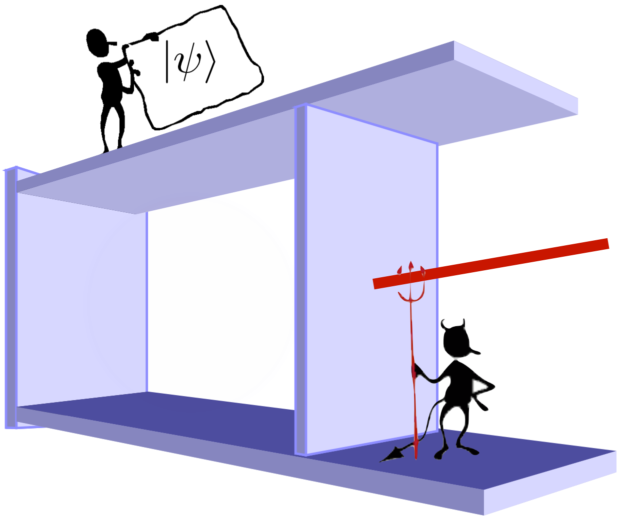
BOOK OF ABSTRACTS



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Quantum Thermodynamics

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Quantum Thermodynamics

Aims of the meeting

The 3^{rd} meeting of the COST Action MP1209 "Thermodynamics at the quantum scale" will be held in Belfast, organised by the Quantum Technology group at Queens University Belfast. The meeting will address the blossoming field of quantum thermodynamics, focusing on the themes addressed by the three working groups of the Action:

- **WG1: Equilibration, thermalisation & emergence of canonical states**
- **WG2: Thermodynamic and information theoretic relations for general quantum systems**
- **WG3: Implementations, from classical to quantum thermodynamic experiments**

QTEQ
QUANTUM TECHNOLOGY at QUEEN'S

Invited Talks

Contributed talks

Posters

Work and correlations

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WORKING GROUP ADDRESSED: 2. THERMODYNAMIC AND INFORMATION THEORETIC RELATIONS FOR GENERAL QUANTUM SYSTEMS

Whats the energy cost of creating correlations? How much work can be stored in a correlated state? Whats the role of entanglement in these processes? The talk explores all these questions, establishing connections between entanglement and thermodynamics as resource theories.

Quantum work distribution in many body systems

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WORKING GROUP ADDRESSED: 3. IMPLEMENTATIONS

The concept of work in thermodynamics is well known and can be well defined in a process in which a property of the system (the position of a piston, the strength of a field) changes from an initial to a final value. In quantum mechanics it has been recently realised that work cannot be associated with the expectation value of an observable but rather with the transition probabilities between energy eigenstates [1]. As a consequence, only the work probability distribution can be properly defined for a given process. In this seminar I will first revise the recent developments concerning the definition of work in quantum mechanics. Then I will discuss a proposal, based on Ramsey interferometry, for measuring the work probability distribution without the need of energy measurements before and after the process [2]. This scheme has recently been implemented in an NMR setting successfully verifying two fundamental relations in thermodynamics, Tasaki-Crooks and Jarzynski relations [3]. Finally, I will mention the latest developments on the work distribution for many-body systems, in particular for 1D spin chains and harmonic oscillators [4, 5], and its relation to equilibrium properties.

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Thermodynamics as a resource theory: foils and clocks

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WORKING GROUP ADDRESSED: 2. THERMODYNAMICS AND INFORMATION

We introduce a general framework for resource theories, and discuss applications to thermodynamics. This framework allows us to analyse different aspects of thermodynamics independently, and helps understand the origin of familiar features of the theory. For instance, what impact does it have to change the structure of the state space from classical to quantum mechanics, or even box world? How do the laws of thermodynamics look if, instead of energy conservation, we impose other physical constraints on the allowed transformations? We can also model the knowledge of an agent acting on a system explicitly, and see how it affects the work gain or cost of a state transformation in different settings.

Moreover, we can analyse the role of clocks as fundamental resources in thermodynamics. We do so by designing a theory that only allows us to apply time-independent Hamiltonians (as opposed to arbitrary reversible operations). This forces us to introduce explicit timing systems to control the implementation of transformations - clocks. Such an expansion of the theory of thermodynamics presents us with problems like the trade-off between the formation work cost and the utility of a clock, and possible catalytic properties of clocks. In this talk, we will discuss first steps towards addressing these issues, and implications for foundational physics.

Experimental studies of fluctuation relations in single-electron boxes

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Being a robust solid-state device, a single-electron box offers a convenient platform to study fluctuation relations. Typically hundreds of thousands of stochastic trajectories can be readily recorded giving rise to high precision in the resulting probability distributions. In this talk, I will present results from the first two experiments on classical fluctuation relations carried out with driven single-electron boxes. In these experiments, we measured the integral and detailed fluctuation relations for dissipated work and entropy production and found that they closely follow the expected theoretical behavior with a large dynamic range. For the entropy, we considered separately two different entropy productions we referrer to as stochastic and thermodynamic. They yield different distributions but both obey the fluctuation relations.

Environmental dynamics, correlations, and the emergence of noncanonical equilibrium states in open quantum systems

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WORKING GROUP ADDRESSED: 1. EQUILIBRATION, THERMALISATION & EMERGENCE OF CANONICAL STATES

Standard open quantum system methods eliminate all information on the environmental state to yield a tractable description of the system dynamics. By incorporating a collective coordinate of the environment into the system Hamiltonian, I shall describe a formalism that circumvents this limitation [1]. Our theory provides straightforward access to important properties of the environmental dynamics that would otherwise be obscured, and allows us to quantify the evolving system-environment correlations. Considering a quantum system coupled to a low frequency environment, we find that the canonical system steady-state predicted by standard perturbative techniques is almost always incorrect. I shall show this to be due to the generation of robust system-environment correlations that persist into equilibrium (heralded also by the emergence of non-Gaussian environmental states) and can be fully characterised by thermal states of the mapped system-collective coordinate Hamiltonian. I shall also outline how non-canonical system states could be investigated experimentally to study deviations from canonical thermodynamics, with direct relevance to molecular and solid-state nanosystems.

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Non-equilibrium statistics and thermodynamic machines with trapped ions

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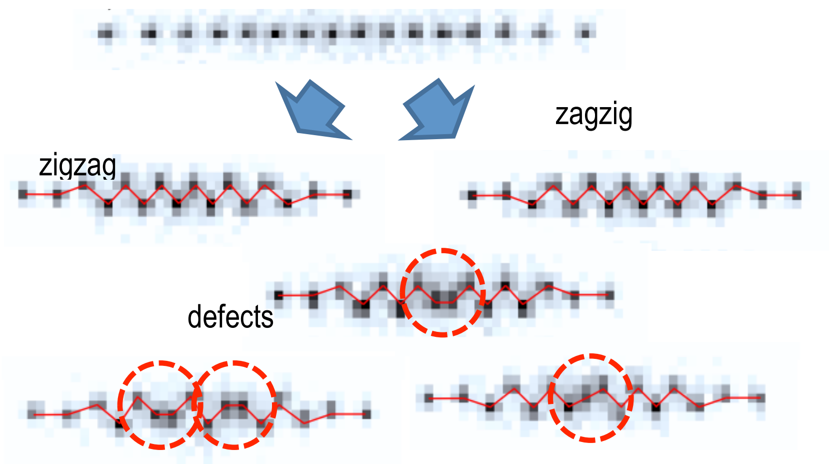
WORKING GROUP ADDRESSED: 3. IMPLEMENTATIONS

Ions confined in a Paul trap arrange in linear crystals and allow for a unique control and analysis. Also, control parameters may be tailored such that a structural phase transition from a linear to a zigzag configuration of the crystal is crossed [1]. Trapped ions serve here as a clean model system to investigate universal laws of defect formation when such transition is crossed fast and causally separated regions form [2]. The amount of defects is predicted by the Kibble-Zurek mechanism [3]. We have experimentally determined the universal scaling exponent for defect formation and confirm the scaling law for the inhomogeneous Kibble-Zurek effect accurately at the percent level [4]. The application of two-dimensional spectroscopy will allow for investigating the phase transition and non-linear coupling of vibrational modes near the critical point [5]. In a second part of the talk we highlight thermodynamic machines scaled down to a single ion [6]. We propose driving the trapped ion in an Otto cycle, oscillating in a specially designed linear Paul trap and coupled to engineered laser reservoirs. Improved performance is expected when employing a squeezed thermal reservoir [7].



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Quantum Thermodynamics of global and local quenches performed on a spin chain

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The thermodynamical cost of performing a sudden quench of the Hamiltonian parameters in the XX spin-1/2 model is investigated. Both global and local quenches are taken into consideration and thermodynamical quantities, such as the total and the irreversible work, are discussed in relation to the many-body physics of the model. The system, described by the Hamiltonian $H_A = h\sum_j S_j^z - J\sum_j[S_j^x S_{j+1}^x + S_j^y S_{j+1}^y]$, is initially prepared in thermal equilibrium at inverse temperature β. Then it is subjected to a rapid change of a.) the global magnetic field, b.) the magnetic field on a single site, and c.) the exchange coupling between just two sites. The irreversible work done in case a.) exhibits signature of the factorization and, in the case of finite-size systems, of the level crossings; for quenches of type b.) the appearance of a localized state can be witnessed by the presence of a peak in the irreversible work. In the latter case the total work is not an extensive quantity and the effects of the interaction of the quenched spin with the rest of the system has been investigated, providing a finite-size scaling analysis of the many-body effects on a local quench [1]. Finally, for the case c.), joining two linear finite chains by establishing a link between them changes the value of the magnetic field at which factorization occurs, allow- ing thus to cross the quantum phase transition point by performing a local action. Moreover, an oscillatory behaviour of the irreversible work with respect to the number of spins joined is found, and it exhibits the same periodicity of the bipartite correlations quantifiers [2].

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Operational Thermodynamics of Open Quantum Systems

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The accurate description of work and heat is one of the main objectives when extending thermodynamics to the regime of individual quantum systems. Exploiting the old but little-known concept of state passivity and, in extension, the notion of ergotropy the amount of work that can be extracted in a cyclic, unitary process [2] we establish a relation between the work potential of an out-of-equilibrium state and the work deposited when creating the same state in a general unitary process. Extending this to general quantum processes described by completely-positive and trace-preserving (CPTP) maps we identify three separate contributions to the energy change: operational work and heat as well as a genuine non-equilibrium part [1]. This new expression of the first law is operationally meaningful as it relates energy contributions to the type of process required for them to be non-zero.

Subsequently, we review a recent operational expression of the second law of thermodynamics [3] and demonstrate consistency with the operational first law when using thermal maps. Finally, the role of majorisation for the operational heat generated under CPTP evolution is highlighted.

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Stochastic thermodynamics for driven quantum open systems

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WORKING GROUP ADDRESSED: 2. THERMODYNAMIC AND INFORMATION THEORETIC RELATIONS FOR GENERAL QUANTUM SYSTEMS

Progress has been made during the last decades in the development of a statistical theory for classical out-of-equilibrium system. In addition to celebrated fluctuation theorems, stochastic thermodynamic now provides both a nice unifying theoretical framework and a useful way for studying these systems experimentally. It was for instance at the heart of the first experimental verification of Landauers principle. This success in understanding classical systems drew interest in similar problems for out-of-equilibrium quantum systems. A set of various fluctuation relations have then been obtained. Severe issues however appeared in the very definition of thermodynamic quantities for quantum systems, so that a unified framework for driven out-of-equilibrium quantum open system is not yet available. We propose to fill this gap by constructing a quantum stochastic thermodynamics based on a quantum trajectory description of quantum open systems. Introduced in the context of quantum optics, these trajectories have recently become relevant physical objects thanks to several experimental breakthrough. This framework allows for definitions at the single trajectory level of basic thermodynamic quantities such as heat transfer, work and entropy. This formalism can then be used to obtained central fluctuation theorems, from which follow more practical fluctuation relations such as for instance Jarzynski and Crooks fluctuation theorems. This framework will be used to get a thermodynamic point of view on processes such as a simplified Landauer erasing protocol or the Landau-Zener transition.

COP at maximum cooling power for strongly coupled quantum fridges

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WORKING GROUP ADDRESSED: 3. IMPLEMENTATIONS

The derivation of general performance benchmarks is important in the design of highly optimized heat engines and refrigerators. To obtain them, one may model phenomenologically the leading sources of irreversibility ending up with bounds which are model-independent, but limited in scope [1]. Alternatively, one can take a simple physical system realizing a (quantum) thermodynamic cycle and assess its optimal operation from a complete microscopic description [2]. In this way, the coefficient of performance (COP), e.g. at maximum cooling rate, may be derived for any strongly coupled quantum refrigerator. Remarkably, we find that no universal or model-independent performance bound may be established for the optimal performance of a quantum fridge, which in general is constrained by the specific system-bath interaction mechanism considered [3].

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Ultimate power of Thermal operations: limitations for thermodynamical processing of coherences

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WORKING GROUP ADDRESSED: 2. THERMODYNAMIC AND INFORMATION THEORETIC RELATIONS FOR GENERAL QUANTUM SYSTEMS

In this work, we study single shot thermodynamics and consider thermodynamical resource, namely, a quantum state out of thermodynamical equilibrium. We analyze possible manipulations of this resource, by Thermal operations [1], consisting of putting the system in contact with a heat bath as a free resource and applying energy preserving operations (we do not consider catalysis), applied in [2] to obtain new definitions of the free energy. We examine how coherences in the energy eigenbasis can be transformed under such operations, and to what extent the transformations are robust, in the sense that they do not require detailed control of the heat bath. We obtained limitations on the inevitable loss of coherences that accompany transitions of the energy spectrum. We show that the limitations are matched in the case of a single qubit, in which case we obtain a full characterization of state to state transformations. It is argued, that for higher dimensions, more severe constraints exist. We also study the power of Thermal operations by comparing the limitations for state transitions with these that can be obtained by weak coupling.

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Gibbs-Preserving Maps outperform Thermal Operations in the quantum regime

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WORKING GROUP ADDRESSED: 2. THERMODYNAMICS AND INFORMATION

We compare two frameworks for characterizing possible operations in quantum thermodynamics. One framework considers Thermal Operations—unitaries which conserve energy. The other framework considers all maps which preserve the Gibbs state at a given temperature. Thermal Operations preserve the Gibbs state; hence a natural question which arises is whether the two frameworks are equivalent. Classically, this is true—Gibbs-Preserving Maps are no more powerful than Thermal Operations. Here, we show that this no longer holds in the quantum regime: a Gibbs-Preserving Map can generate coherent superpositions of energy levels while Thermal Operations cannot. This gap has an impact on clarifying a mathematical framework for quantum thermodynamics.

In particular, our result exposes a problem of time control as a resource, which is an aspect that current efforts in modeling thermodynamics of quantum systems have ignored until now.

Our results are presented in [1].

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Emergence of coherence and the dynamics of quantum phase transitions

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Working group addressed: 1. Equilibration, Thermalisation & Canonical States

Quantum systems out of equilibrium pose some of the most exciting puzzles in many-body physics and quantum thermodynamics, including questions of transport, equilibration, and thermalisation. The dynamics of these systems becomes particularly complicated around quantum phase transitions, which are a true quantum phenomenon and can themselves not be captured within the theory of classical thermodynamics. When dynamically crossing such a transition, the closing of the gap at the critical point causes a breakdown of adiabaticity of the evolution and thus, defects are introduced into the system. This raises the following questions: How does a literal phase transition happen? To what extent can static ground state properties be probed by a dynamical experiment? When entering a critical phase associated with an infinite correlation length, at what rate and by what mechanism will coherence build up. While free models allow for an exact treatment, serving as a theoretical laboratory, the behaviour of complex many-body systems at their phase transition is still largely an open question. Ultracold atoms in optical lattices provide a clean, well isolated, and highly controllable system and allow for a thorough study of this question, in models that are, in any meaningful sense of the word, far from being integrable. In this talk, we will explore the Mott to superfluid transition by slowly decreasing the depth of the optical lattice, thus crossing the critical point. We verify our experimental results by extensive numerical simulations of the Bose-Hubbard model, thus performing an instance of a certified quantum simulation. For intermediate ramp speeds, we observe a power-law behaviour of the coherence length. This power-law is reminiscent of the Kibble-Zurek mechanism, which provides a simple and beautiful yet somewhat crude guideline for what one should expect for the growth of coherence and the density of defects following asymptotically slow ramps. We find a complex behaviour, uncovering intriguing new physics that cannot be captured by this mechanism or any other known model. By using the full power of the quantum simulation, we also explore the emergence of coherence in higher dimensions, finding remarkably similar results to the one-dimensional case. We connect our findings with insights into close-to-adiabatic quantum evolutions and carefully compare our continuous ramp setting with concepts of equilibration and thermalisation associated with sudden quenches. We also put the results into the context of notions of information propagation and Lieb-Robinson bounds.

Steps towards exploring the quantum Landauer principle experimentally

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WORKING GROUP ADDRESSED: 2. THERMODYNAMIC AND INFORMATION THEORETIC RELATIONS FOR GENERAL QUANTUM SYSTEMS

Very recently, interferometric methods have been proposed to measure the full statistics of work performed on a driven quantum system [Dorner et al. Phys. Rev. Lett. **110**, 230601 (2013)] and [Mazzola et al. Phys. Rev. Lett. **110**, 230602 (2013)]. These proposals are one possible route to the tangible experimental exploration of quantum thermodynamics, a subject which is the centre of much current attention due to the current control of mesoscopic quantum systems. In this talk I will demonstrate that a modification of the phase estimation protocols can be used in order to measure the heat distribution of a quantum process. Furthermore, Using the operational framework of completely positive, trace preserving operations and thermodynamic fluctuation relations, we derive a lower bound for the heat exchange in a Landauer erasure process on a quantum system. I will also mention recent attempts to construct a quantum thermodynamics of an open quantum system in an operational manner.

Tightening the second law of thermodynamics for restricted baths

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Working group addressed: 3. Implementations

The most operationally meaningful formulation of the second law of thermodynamics is the so called maximum work principle: the maximal work one can extract from a system attached to a bath is given by the difference of initial and final free energies of the system. The law is universal: it does not depend on the details of the bath. Yet, while working with small systems, we face different kinds of limitations connected to the fact that the bath is not infinite or it cannot be engineered to have correct macroscopic spectrum, etc. A fundamental question then would be whether one can put additional limitations on the extractable work which will respect the new constraints but will still be independent on the other details of the bath. In case of fixed dimensionality of the Hilbert space of the bath we find general dimensionality-dependent bounds on the corrections to free energy difference formula. We further study another kind of limitation where it is not the dimensionality that is bounded but the fine tuning in the bath. We do so by considering an ensemble of identical spins as a bath. There we prove that the lack of fine tuning is compensated by taking the continuum limit and we find the scaling of the corresponding correction term. The role of correlations built up between the system and the bath and within the bath is also studied.

Fluctuation theorems in systems in contact with several baths: theory and experiments

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WORKING GROUP ADDRESSED: 2. THERMODYNAMIC AND INFORMATION THEORETIC RELATIONS FOR GENERAL QUANTUM SYSTEMS

I will first consider a harmonic chain coupled to two or more heat baths at different temperatures. I will use this model to introduce and discuss the fluctuation theorem that sets precise constraints on the fluctuations of the heat transfer between the different reservoirs. I will generalize these results to the case of systems with general interaction potential. I will then show some experimental results for a system formally equivalent to a harmonic chain with different heath baths, and show that a conservation law for the total entropy exists.

Finally, I will discuss the general case of a system in contact with multiple energy and particle baths, and show that there exists a fluctuation theorem that involves only the energy and the particle currents and that holds at any time.

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Cavity-Optomechanics meets Thermodynamics

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WORKING GROUP ADDRESSED: 3. IMPLEMENTATIONS

Optical levitation is a promising approach to realize mechanical resonators of unprecedented mechanical quality, which are strongly desired, e.g., in cavity optomechanics. Coupling the levitated object to the light field of an optical cavity opens up new possibilities for control and readout of its center-of-mass motion, for example, sideband cooling. Recently strong interest has been developed in establishing this system as a new kind of quantum mechanical light matter interface. In this presentation, I will argue that levitated cavity-optomechanics is also an excellent system for experiments at the interface of quantum optomechanics and thermodynamics. I will start by introducing the relevant principles and present our recent experimental results on cavity-cooling of a levitated sub-micron particle. From that point on I will deviate from the usual route towards quantum optomechanics and discuss levitated optomechanics in the context of thermodynamics.

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Timing in Quantum Thermodynamics

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Recently, there have been many advances towards a resource-theoretic modelling of quantum thermodynamics. The questions addressed range from the development of abstract resource theoretic frameworks [5] and conceptual connections to thermodynamics [15] to specific analyses of thermal operations and related frameworks [11, 3, 2, 8, 13, 12, 6, 7]. Thermal operations formalise the thermodynamic operation of coupling a system S to a heat bath. Formally, they consist of adding to S a system (the bath) with an arbitrary Hamiltonian in a thermal state γ at fixed inverse temperature β, applying any unitaries commuting with the total Hamiltonian of system and bath on the joint system and then discarding subsystems. While for diagonal (i.e. classical) states there is a full characterisation of thermal operations in terms of thermo-majorization criteria [8], sufficient conditions have so far not been found in general to decide whether one can transform between two given (possibly coherent) states by means of thermal operations. As a step in this direction, it has been noted that thermal operations are covariant with respect to the symmetry of Hamiltonian evolution on the system [12], which corresponds to operations covariant with respect to the U(1) symmetry group. There is a wide literature on symmetries and covariant operations ranging from a discussion on quantum reference frames [4] to resource theoretic models deriving specific monotones, in part derived from entanglement theory [14]. Among the works discussing U(1) symmetry, Janzing et al [10, 9] have studied the aspect of clocks. Indeed, each non-symmetric state with respect to Hamiltonian evolution constitutes a timing resource, as due to its non-trivial dynamics it can be used to act as a clock. Transformability by means of time (U(1))-covariant operations induces a structure that can then be translated as clock ordering.

This yields a complex role of time covariance in thermodynamics from an operational perspective: on the one hand, we usually consider as free the implementation of unitaries that commute with the total Hamiltonian. These, however, in general require external control and thus access to a clock in order to be implemented. On the other hand, the specification of thermal operations explicitly bans the use of such clock systems. To make things worse, in the very description of state transformation tasks, when considering non-classical states with non-trivial dynamics, we implicitly assume a reference frame relative to which these states are defined, that is, a (global) clock. Since timing appears to be a delicate concept in its relation to thermodynamics, one would like to require all underlying assumptions to be made explicit. Finally, one might want to allow, from an operational perspective to thermodynamics, the catalytic use of external clock systems [1] in order to create coherence. However, the mere requirement for a system to be catalytic for such specific tasks does not seem to coincide with the clock ordering defined through time-covariant operations (as the system used in [1] degrades as a clock through its otherwise catalytic use). We analyse how to fit these considerations into a general resource-theoretic framework [5] in order to gain further insight into the issue of timing in quantum thermodynamics. This in particular provides a promising approach for treating approximate clock order and state transformations, an issue that has previously not been considered.

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Quantum Systems Equilibrate Rapidly for Most Observables

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Now that the emergence of equilibration is well established for quantum systems, the community has turned its attention to the time scales in which systems equilibrate [210]. However, results in this regard have been puzzling. While attempts to derive the typical time scale of some specific systems have resulted in very fast equilibration [3, 11] , attempts to upper bound equilibration of generic systems have resulted in extremely long equilibration times [2] . In this work, we connect these opposite results, by showing that fast equilibration is always the typical case, while there always exist some very slow observables (that we define explicitly) which saturate the upper bound.

Considering any Hamiltonian, any initial state, and measurements with a small number of possible outcomes compared to the dimension, we show that most measurements are already equilibrated. To investigate non-trivial equilibration we therefore consider a restricted set of measurements. When the initial state is spread over many energy levels, and we consider the set of observables for which this state is an eigenstate, most observables are initially out of equilibrium yet equilibrate rapidly. Moreover, all two-outcome measurements, where one of the projectors is of low rank, equilibrate rapidly.

Finally, considering any non-degenerate Hamiltonian and any pure initial state spread over many energy levels, we define an observable which takes an extremely long time to equilibrate (easily longer than the age of the universe).

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Limits to catalysis in quantum thermodynamics

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Quantum thermodynamics is a research field that aims at fleshing out the ultimate limits of thermodynamic processes in the deep quantum regime. A complete picture of quantum thermodynamics allows for catalysts, i.e., systems facilitating state transformations while remaining essentially intact in their state, very much reminding of catalysts in chemical reactions. In this work, we present a comprehensive analysis of the power and limitation of such thermal catalysis. Specifically, we provide a family of optimal catalysts that can be returned with minimal trace distance error after facilitating a state transformation process. To incorporate the genuine physical role of a catalyst, we identify very significant restrictions on arbitrary state transformations under dimension or mean energy bounds, using methods of convex relaxations. We discuss the implication of these findings on possible thermodynamic state transformations in the quantum regime.

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A derivation (and quantification) of the third law of thermodynamics

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The third law of thermodynamics has a controversial past and a number of formulations due to Planck, Einstein, and Nernst. Its most accepted version, the unattainability principle, states that any thermodynamic process cannot reach the temperature of absolute zero by a finite number of steps and within a finite time. Although formulated in 1912, there has been no proof of the principle, and the only evidence we have for it is that particular cooling protocols become less efficient as a system is cooled. Here, we provide the first proof of the unattainability principle, and further quantify the time and number of steps it takes to cool a system to any particular temperature. Our result holds for any initial state and any process, including those such as laser cooling which exploit the laws of quantum theory. They thus provide quantitative ultimate bounds on fundamental transformation processes. Our results also place ultimate bounds on the speed at which information can be erased.

Thermodynamics with nanospheres levitated in a vacuum

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WORKING GROUP ADDRESSED: 3. IMPLEMENTATIONS

Nanoscale objects can be levitated by optical fields in a vacuum, creating mechanical oscillators with very high quality factors. This makes the nanoparticle extremely sensitive to external perturbations, making the levitated system ideal for studying the interaction between a particle and the bath it is immersed in. Optically levitated nanospheres have been used to study relaxation to equilibrium [1] and the non-equilibrium dynamics arising when the nanosphere can heat the bath [2]. Further to this, levitated nanospheres could be coupled to quantum systems such as clouds of cold atoms, and even cooled to the quantum level themselves [3], opening many opportunities in the field of quantum thermodynamics.

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Relaxation of interacting many-body systems under purely dissipative quantum dynamics

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We study the relaxation dynamics of quantum many-body systems that undergo purely dissipative dynamics through non-classical jump operators that can establish quantum coherence. We contrast the relaxation dynamics of this class of systems with those evolving via classical rate equations towards a stationary state with the same values of diagonal or classical observables as in the quantum system but where coherences are absent. We focus in particular on spin systems whose dynamics becomes correlated and complex due to dynamical constraints, inspired by kinetically constrained models (KCMs) of classical glasses. We show that in the quantum case the relaxation of the coherences can be orders of magnitude slower than that of diagonal observables. Finally, we show that the relaxation of strongly interacting Rydberg atoms under electromagnetically induced transparency (EIT) conditions can indeed, in an appropriate limit, be described by such a purely dissipative dynamics with non-classical jump operators. We establish a connection between the Rydberg system and the discussed KCMs and investigate the limitations of using a classical rate equation model to capture the non-equilibrium behaviour of this system.

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Complete positivity and the second law in a driven open quantum circuit

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We discuss a possible experimental setting where to study the completely positive character of the reduced dynamics of an open quantum system and its connections with the second law of thermodynamics.

The open quantum system paradigm is a remarkably successful way to cope with the unavoidable weak interactions of quantum systems with their environment. In most physical applications there are no initial statistical correlations between system and environment; in such cases, a reduced dynamics for the open quantum system alone can be derived by eliminating the environment degrees of freedom. The corresponding time-evolution is irreversible and characterized by dissipation and noise; furthermore, for physical consistency reasons, it is required not only to preserve the positivity of the time-evolving states of the system, but also to be completely positive, in order to guarantee the positivity at all times of the spectrum of any entangled state of the open quantum system statistically coupled to any dynamically inert finite level system. This justification is often criticised in the literature as an abstract mathematical artefact that excludes more general dissipative dynamics. Indeed, due to complete positivity, the generator of the reduced dynamics assumes the so-called Lindblad form to which there correspond specific physical constraints: typically, a hierarchy among the decay times of the various entries of the density matrices that describe the state of the open quantum system.

Until now, the only experimental studies of the completely positive character of a dissipative dynamics have been performed by checking the above mentioned hierarchy, in general a difficult experimental task. Instead, we offer a different strategy based upon the thermodynamic behaviour of open quantum systems. Indeed, complete positivity was soon recognized to imply the positivity of the internal entropy production as required by the second law of thermodynamics; however, so far no concrete physical context where to study such a connection has been proposed. We shall focus upon a model consisting of three electrons moving in a micro-circuit consisting of a three-site loop, under the action of a periodical driving and of a weak coupling to a thermal bath of free harmonic oscillators in equilibrium at temperature T. This system, effectively describable as an open 2-level system, has been introduced to study the dependence of the asymptotic current that sets in because of the weak interaction with the thermal environment on the period of the external driving. We study its behaviour from a thermodynamic point of view, and show that the non-completely positive Redfield dynamics considered in the model violates a certain formulation of the second law of thermodynamics. The pattern of these violations is related to the time behaviour and asymptotic behaviour of the current supported by the quantum micro-circuit, which differs from the one obtained using standard weak-coupling techniques that lead to completely positive time-evolutions. Experimental investigations of the current behaviour would then offer a test both of complete positivity and of the second law of thermodynamics in open quantum system dynamics.

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Irreversible work and inner friction in quantum thermodynamic processes

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I will discuss the thermodynamics of closed quantum systems driven out of equilibrium by a change in a control parameter and undergoing a unitary process in terms of fluctuation relations and entropy production [1, 2]. In doing this, I will compare the work actually done on the system with the one that would be performed along ideal adiabatic and isothermal transformations. While the comparison with the latter naturally leads to the introduction of the average irreversible work, that with the former leads to the concept of inner friction. These two quantities can be treated on equal footing, as both can be linked with the heat exchanged in thermalization processes. Furthermore, it has been shown that the irreversible work is given by the relative entropy between the actual final state of the system and an equilibrium state at the same initial temperature [3] and, similarly, I will show that the inner friction too can be expressed as a relative entropy. Finally, I will discuss the entropy production associated with the inner friction and derive a fluctuation relation for this quantity.

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Thermodynamics for individual Quantum Systems

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We present a framework for extending standard thermodynamics to individual quantum systems, including explicitly a thermal bath and work-storage device (essentially a weight that can be raised or lowered). We prove that the second law of thermodynamics holds in our framework, and give a simple protocol to extract the optimal amount of work from the system, equal to its change in free energy. Unlike some other recent approaches, our results apply to any quantum system in an arbitrary initial state, in particular including non-equilibrium situa- tions (i.e. states with coherences between energy levels). Furthermore, our optimal protocol is essentially reversible, similar to classical Carnot cycles.

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Equivalence of Reciprocating Quantum Heat Engines

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We show that in the limit where each stroke only slightly modifies the systems density matrix, both two-stroke and four-stroke quantum engine are equivalent to the same continuous heat machine. In this regime, the equivalent engines not only have the same steady state density matrix but also have the same work and efficiency. A mathematical result indicates that increasing the strokes number cannot be used to increase the regime of equivalence without violating the Markovianity of the baths. We also discuss the behaviour of the engines outside the regime of equivalence where the engines behave significantly different from each other.

Housekeeping heat and work in out of equilibrium quantum systems

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Previous works (T. Speck, U. Seifert, J. Phys. A: Math. Gen. 38 (2005) L581-L588) suggest that the process of keeping a system (in contact with a thermal bath) in a out-of-equilibrium target state ρ_s can be achieved by simply restoring the heat dissipated by the system in the thermal bath. Here we treat this problem form a fully quantum mechanical point of view. Using mathematical tools recently developed (D. Reeb, M. M. Wolf, arXiv: 1306:4352v2 (2014)), we prove that this is possible when the state ρ_s commutes with the local Hamiltonian of the system H_s. In this case, in order to keep the system in the state ?s it is sufficient to compensate for the heat dumped in the bath by transferring the same amount of heat to the system from a second heat reservoir. We also express the amount of heat needed in terms of the state ρ_s and the thermal equilibrium state ρ_β only.

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Most efficient quantum thermoelectric at finite power output

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Machines are only Carnot efficient if they are reversible, but then their power output is vanishingly small. Here we ask, what is the maximum efficiency of an irreversible device with finite power output? We use a nonlinear scattering theory to answer this question for thermoelectric quantum systems; heat engines or refrigerators consisting of nanostructures or molecules that exhibit a Peltier effect. We use the scattering theory to derive the first and second laws of thermodynamics for thermoelectric quantum systems [1]. We then find that quantum mechanics places an upper bound on both power output, and on the efficiency at any finite power [2]. The upper bound on efficiency equals Carnot efficiency at zero power output, but decays with increasing power output. It is intrinsically quantum (wavelength dependent), unlike Carnot efficiency. This maximum efficiency occurs when the system lets through all particles in a certain energy window, but none at other energies. A physical implementation of this is discussed, as is the suppression of efficiency by a phonon heat flow.

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Hysteresis, in and out of equilibrium

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WORKING GROUP ADDRESSED: 1. EQUILIBRATION, THERMALISATION & CANONICAL STATES

The random-field Ising model (RFIM) is one of the simplest statistical-mechanical models that captures the anomalous irreversible collective response seen in a wide range of physical, biological, or socioeconomic situations in the presence of interactions and intrinsic heterogeneity or disorder. When slowly driven at zero temperature, it can display an out-of-equilibrium phase transition associated with critical scaling (crackling noise), while it undergoes at equilibrium, under either temperature or disorder-strength changes, a thermodynamic phase transition. We show that the out-of-equilibrium and equilibrium critical behaviors are in the same universality class: they are controlled, in the renormalization-group (RG) sense, by the same zero-temperature fixed point [1]. We do so by combining a field-theoretical formalism that accounts for the multiple metastable states and the exact (functional) RG. The same formalism is extended also to study relaxation dynamics via Langevin equation approach. We recover the extreme (exponential) lengthening of the relaxation time [2].

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Multipolaron Ground State Ansatz for the Spin-Boson Model

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WORKING GROUP ADDRESSED: 1. EQUILIBRATION, THERMALISATION & CANONICAL STATES

We explore the nature of the ground state of the continuum Spin-Boson model by means of a novel expansion in a basis of polaron (spin-state dependent displaced oscillator) states [1, 2]. We take into account correlations between the environment (a continuum of bosons) and the spin system explicitly, allowing for the identification of macroscopic spin-bath entanglement. The form of the ansatz is designed to allow for the exploration of both weak and strong spin-bath coupling, and also the characterisation of quantum phase transitions within the model. Previous work considering linear (Ohmic) dissipation has shown much promise [3] and we are extending these results into the sub-linear (sub-Ohmic) regime. We expect that insights gained from the zero temperature limit will also provide the first step towards implementations of finite temperature and dynamical ansatzes.

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Non-equilibrium Quantum Thermodynamics of an Ideal Optomechanical System

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WORKING GROUP ADDRESSED: 2. THERMODYNAMICS AND INFORMATION

In the framework of statistical mechanics, fluctuations theorems are known to provide a tight link between the statistical fluctuations experienced by a system arbitrarily far from equilibrium, and the information encoded in its equilibrium properties. Surprisingly, nothing prevents these results to hold down to the quantum realm, where quantum fluctuations, besides thermal ones, play a non negligible role. This fundamental aspect, together with the technological push towards devices miniaturization, has stimulated a genuine interest in addressing non-equilibrium thermodynamics at the mesoscopic scale, witnessing a fruitful interplay with ideas originally developed in quantum information science. Among the physical platforms where to explore these features, optomechanical systems appear as very suited candidates, both because they provide a spectacular example of macroscopic objects working deeply in the quantum regime, and because of the high level of tuneability and control they can offer. We explore the dynamical response of an optomechanical system, consisting of a cavity mode interacting with a movable mirror, after a sudden quench of the radiation-pressure coupling. This provides the first instance of investigation of out-of-equilbrium thermodynamics of non-linearly coupled bosonic systems in the quantum regime. In particular, we consider an isolated systems initially in a thermal equilibrium state, and, following the unitary dynamics induced by the quench, we explicitly compute the most relevant thermodynamical figures of merit, such as the full statistics of the work distribution, the free energy difference and the irreversible work generated during the process. Moreover, by explicitly solving the unitary dynamics, we can monitor the evolution of the coupled system at any time. We found that turning on the coupling results in no production of work onto the system. On the other hand, adding a displacement on the mirror, a non-zero value of the average work is recovered. These results set a benchmark for future investigations in the open case scenario.

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Shortcuts to adiabaticity in genuinely many-body interacting Hamiltonians

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WORKING GROUP ADDRESSED: 3. IMPLEMENTATIONS

Coherently controlling quantum systems has long stood as a difficult task, an issue that is compounded when we move beyond small sizes and truly wish to manipulate interacting many-body quantum systems. By virtue of the adiabatic theorem, we are able to ensure a quantum system remains in an eigenstate (e.g., its ground state) during any given evolution. However, the obvious limitation of this technique is it operates on a long-time scale and thus requires equally long control times, rendering it extremely difficult experimentally. Motivated by the need for practical means to manipulate any given quantum system, current efforts have developed along two paths: optimal control and shortcuts to adiabaticity. In particular, the latter can be achieved by means of transitionless quantum driving (TQD) [1] which involves adding a correction term to the original Hamiltonian to ensure there are no transitions between the eigenstates, and will be our focus. We examine the requirements when TQD is applied to the many-body interacting Lipkin-Meshkov-Glick model [2]. By means of both numerical and analytical approaches we assess the requirements for full TQD, as well as examining the performance of non-optimal shortcuts, i.e., simplified correction terms that do not achieve perfect TQD but that do not require complete knowledge of the spectrum and/or may be experimentally easier to implement.

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Out of equilibrium thermodynamics of quantum harmonic chains

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WORKING GROUP ADDRESSED: 2. THERMODYNAMICS AND INFORMATION

The thermodynamic implications for the out-of-equilibrium dynamics of quantum systems are to date largely unexplored, especially for quantum many-body systems. In this paper we inves- tigate the paradigmatic case of an array of nearest-neighbor coupled quantum harmonic oscil- lators interacting with a thermal bath and subjected to a quench of the inter-oscillator coupling strength. We study the work done on the system and its irreversible counterpart, and charac- terize analytically the fluctuation relations of the ensuing out-of-equilibrium dynamics. Finally, we showcase an interesting functional link between the dissipated work produced across a two- element chain and their degree of general quantum correlations. Our results suggest that, for the specific model at hand, the non-classical features of a harmonic system can influence significantly its thermodynamics.

Assessing the non-equilibrium thermodynamics in a quenched quantum many-body system via single projective measurements

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I analyse the nature of the statistics of the work for a quantum many-body system brought out of equilibrium. For a sudden quench and for an initial state which commutes with the initial Hamiltonian, it is possible to retrieve the whole non-equilibrium thermodynamics via single projective measurements of observables. I the qualitative implications for the statistics of work coming from considering processes described by operators that either commute or do not commute with the unperturbed Hamiltonian of a given system. I derive an expression that allows me to give a physical interpretation, for a thermal initial state, to all of the cumulants of the work in the case of quenched operators commuting with the unperturbed Hamiltonian. In the commuting case the observables needed to be measured have an intuitive physical meaning. Conversely, in the non-commuting case I show that some difficulties are faced in providing a clear-cut physical interpretation to the cumulants. This circumstance makes the study of the physics of the system non-trivial and highlights the non-intuitive phenomenology of the emergence of thermodynamics from the fully quantum microscopic description. I illustrate my ideas with the example of the Ising model in a transverse field showing the interesting behavior of the high-order statistical moments of the work distribution for a generic thermal state and linking them to the critical nature of the model itself.

On the equilibration time scales for small subsystems of a closed quantum system

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WORKING GROUP ADDRESSED: 1. EQUILIBRATION, THERMALISATION & CANONICAL STATES

One still open problem is understanding, from first principles, under what condition a closed quantum system equilibrates quickly with respect to some observable. Understanding these time scales would be a step forward into a much deeper problem, the one of understanding the time scales for thermalization of quantum systems. Recently there have been promising advances (see Artur Malabarbas talk). In particular, we have learnt that typical (drawn from the Haar measure) observables equilibrate rapidly, and yet one can construct observables which take an extremely long time to approach equilibrium (in a time proportional to the Hilbert space dimension d). However, these results tell us little about the times for a single given physical observable. In this work we provide a new upper bound on the equilibration time scales. Under the assumption that the initial state is spread over many energy levels, and certain assumptions about the distribution of the matrix elements of an observable we find that for very mixed initial states this new bound gives much better results than previously known, results which do not scale with the Hilbert space dimension d. As a corollary we give an observable-dependent time scale estimate for observables acting on a small subsystem of a bigger closed system, and contrast it with an analytic example. This is a result towards understanding the conditions under which subsystems immersed in an environment equilibrate rapidly.

Matrix-Product operators as a numerical tool for transport

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Matrix-Product states and their counterpart for observables, known as MPO, have proven to be a powerful tool to understand the non-equilibrium behaviour of many-body systems. Based on a carefully optimized code, we numerically explore transport in spin chains and highlight connections to thermalisation and equilibration in these models. In particular, we address the question to what extend Lieb-Robinson bounds are saturated and how well they can capture the true dynamical behaviour of local observables.

References

[1] R. Landauer, IBM J. Res. Dev. **5**, 183 (1961).

Environmental dynamics, correlations, and the emergence of noncanonical equilibrium states in open quantum systems

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Standard open quantum system methods eliminate all information on the environmental state to yield a tractable description of the system dynamics. By incorporating a collective coordinate of the environment into the system Hamiltonian (Fig. 1), we develop a formalism that circumvents this limitation. Our theory provides straightforward access to important properties of the environmental dynamics that would otherwise be obscured, and allows us to quantify the evolving system-environment correlations. Considering a quantum system coupled to a low frequency environment, we find that the canonical system steady-state predicted by standard perturbative techniques is almost always incorrect [2]. We show this to be due to the generation of robust system-environment correlations that persist into equilibrium (heralded also by the emergence of non-Gaussian environmental states) and can be fully characterised by thermal states of the mapped system-collective coordinate Hamiltonian. We outline how noncanonical system states could be investigated experimentally to study deviations from canonical thermodynamics, with direct relevance to molecular and solid-state nanosystems.

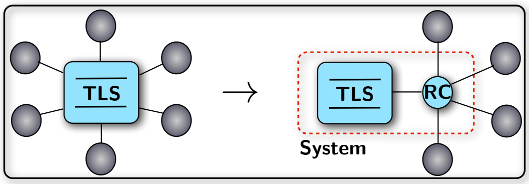

Figure 1: A TLS interacting with a bosonic environment (left) is mapped to a TLS coupled only to a collective mode, which is in turn damped by a residual bath (right).

References

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Autonomous work extraction within a Szilard engine model

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Working group addressed: 2. Thermodynamics and information

A fundamental question of thermodynamics related to Landauers principle is how much work can be extracted from a physical system in a known state, given access to a thermal bath. In recent years, particular attention has been given to this question with respect to small quantum systems, where the standard theory of thermodynamics is not necessarily applicable. Here, we consider one particular aspect of work extraction procedures: autonomy. We call a procedure autonomous if the energy-conserving evolution of the involved systems is described by a time-independent Hamiltonian and no external control is needed. To tackle this question we investigate the work extraction process of a one-dimensional Szilard engine in a semi-classical model.

Within this semi-classical model, we have done numerical simulations of the time evolution of the piston for different boundary conditions. We varied between an elastic box and a box that thermalizes the pistons momentum when it reaches a wall. In the elastic case very large fluctuations in the pistons position can be observed. Hence, the energy extracted from the pistons position is highly unordered and cannot be regarded as work. This changes when we use thermal boundary conditions. There are still fluctuations in the pistons position, but we can observe an increased probability to find the piston close to the wall.

Our main finding is that work extraction in a Szilard engine seems to be possible if we allow for friction in the form of thermal boundary conditions. This raises the question whether friction is necessary for a Szilard engine to produce ordered energy. At least in our model it seems to be essential.

Landauers principle and non-Markovianity in two-body open quantum systems

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WORKING GROUP ADDRESSED: 2. THERMODYNAMICS AND INFORMATION

The aim of the project is to use collision-based models for the description and modeling of quantum open-system dynamics to provide a microscopic analysis of out-of-equilibrium thermodynamics, its link with (quantum) information-to-energy conversion, and the influences that non-Markovianity has on such processes. In the standard collision-based picture, a quantum system S is made to interact with a complex environment consisting of multiple elementary constituents, which we dub here sub- environments and label E_j. The system interacts sequentially with the sub-environments. Typically, the $S - E_j$ interaction is taken to have the form of a variable-strength collision, at the end of which the specific sub-environment E_j acquires information on the state of S. Intra- environment collisions, interspersing the $S - E_j$ and $S - E_{j+1}$ interactions, can be considered in this picture to model information propagation mechanisms of key relevance for the sake of this abstract. In fact, such intra-environment interactions can result in non-negligible environmental memory effects that, in turn, result in an explicitly non-Markovian dynamics of the system only. The characterization of the reduced dynamics of S against the specific form of the system-environment and intra-environment coupling has been the subject of a substantial amount of work, most recently performed by me in Belfast (in collaboration with Mauro Paternostro) [1] and the group led by Massimo Palma in Palermo (in collaboration with Vittorio Giovannetti in Pisa) [2]. Such endeavours have shown the emergence of highly non- trivial features in the reduced evolution of S, which can be tuned within an ample range of dynamical forms interpolating fully memory-less and strongly non-Markovian maps. The project moved significantly away from the assessment of non-Markovianity in collision-based models to address quantitatively the thermodynamics arising from such a flexible microscopic model for open-system dynamics. In particular, we analysed the fluxes of heat leaving/entering the state of the system as a result of its series of collisions with the sub-environments and compared them to the entropy decrease (a' la Landauer [3]) and another recently proposed bound to the dissipated heat [4]. We have considered multiple models and have both numerical and analytic work done for all, however only a couple would be presented during the talk.

References

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[3] R. Landauer, IBM J. Res. Dev. **5**, 183 (1961).

[4] J. Goold, M. Paternostro, and K. Modi, arXiv:1402.4499 (2014).

Thermodynamics of levitated nanopheres

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WORKING GROUP ADDRESSED: 3. IMPLEMENTATIONS

Nanoscale objects can be levitated by optical fields in a vacuum, creating mechanical oscillators with very high quality factors. This makes the nanoparticle extremely sensitive to external perturbations, making the levitated system ideal for studying the interaction between a particle and the bath it is immersed in. Optically levitated nanospheres have been used to study relaxation to equilibrium [1] and the non-equilibrium dynamics arising when the nanosphere can heat the bath [2]. Further to this, levitated nanospheres could be coupled to quantum systems such as clouds of cold atoms, and even cooled to the quantum level themselves [3], opening many opportunities in the field of quantum thermodynamics.

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[3] T. S. Monteiro et al. New J. Phys. **15**, 015001 (2013).

Synchronizing a single-electron shuttle to an external drive

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WORKING GROUP ADDRESSED: 3. IMPLEMENTATIONS

The nanomechanical single-electron shuttle is a resonant system in which a suspended metallic island oscillates between and impacts at two electrodes. This setup holds promise for one-by-one electron transport and the establishment of an absolute current standard. While the charge transported per oscillation by the nanoscale island will be quantized in the Coulomb blockade regime, the frequency of such a shuttle depends sensitively on many parameters, leading to drift and noise. Instead of considering the nonlinearities introduced by the impact events as a nuisance, here we propose to exploit the resulting nonlinear dynamics to realize a highly precise oscillation frequency via synchronization of the shuttle self-oscillations to an external signal. We link the established phenomenological description of synchronization based on the Adler equation to the microscopic nonlinear dynamics of the electron shuttle by calculating the effective Adler constant analytically in terms of the microscopic parameters.

Minimising heat dissipation of bit erasure by controlling a finite-size quantum reservoir

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WORKING GROUP ADDRESSED: 2. THERMODYNAMICS AND INFORMATION

We determine the optimal unitary evolution on a composite system composed of a qubit, the object to be erased, and a thermal reservoir of dimension $d < \infty$, so as to minimise the heat dissipation to the reservoir conditional on maximally reducing the entropy of the qubit: of maximally erasing its information. We consider the simple example of erasing a maximally mixed qubit using a reservoir with a uniform energy gap between consecutive eigenstates, such as a harmonic oscillator. We show that in the limit as both d and Hamiltonian norm tend to infinity the heat dissipation due to a $\log(2)$ reduction in entropy obeys the inequality $\beta\Delta Q \geqslant 1$, with the equality reached in the limit of the energy spectrum forming a continuum. We also show that in the presence of pure dephasing bit erasure can be made more efficient by both increasing the dimension of the reservoir and decreasing the energy gap. Furthermore, we provide a scheme for decreasing heat dissipation by using an auxiliary system in addition to the thermal reservoir. We conclude by showing that if the qubit is a subsystem of a thermal reservoir, heat dissipation due to maximal bit erasure is minimised when the qubit is initially uncorrelated with the other subsystems of the reservoir.

Quantum Thermometry of Strongly Correlated Systems

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WORKING GROUP ADDRESSED: 3. IMPLEMENTATIONS

While the existence of quantum correlations on all length scales at zero temperature is the most characteristic feature of continuous phase transitions and signals the emergence of a new order, at finite temperatures quantum and thermal fluctuations coexist fading such emergence. Here we investigate, however, how this fading can be realistically used as a quantum thermometer for strongly correlated systems built from ultracold lattice gases. Using as a measuring strategy the Quantum Non Demolition Spectroscopy, we present our preliminary results for the XX and Ising spin models.

Thermal Transport on a Chain of Oscillators coupled to Individual Baths

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WORKING GROUP ADDRESSED: 1. EQUILIBRATION, THERMALISATION & CANONICAL STATES

In this work we will describe the dynamics of a system composed by an arbitrary number of oscillators, each of them attached or not to thermal reservoirs at arbitrary temperatures. We construct analytical solutions for the oscillators-baths system dynamics also providing analytical formulas for the currents and for the mean value of energy of a system evolving under a generic Lindblad master equation for an arbitrary number of degrees of freedom when the Hamiltonian is quadratic and the Lindblad operators operators are linear.

By the end, we analyze some conditions over the transport of heat among the oscillators of the chain.

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[1] R. Landauer, IBM J. Res. Dev. **5**, 183 (1961).

Non-equilibrium relaxation transport of ultracold atoms

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WORKING GROUP ADDRESSED: 2. THERMODYNAMICS AND INFORMATION

We analyze the equilibration process between two either fermionic or bosonic reservoirs containing ultracold atoms with a fixed total number of particles that are weakly connected via a few-level quantum system [1]. Extending our previous work [2], we allow for both the temperatures and particle numbers of the reservoirs to evolve in time. To this end, we use a Born-Markov-Secular master equation which reduces to a rate equation and determine the thermodynamic variables of the reservoirs, i.e., temperature T, chemical potential μ and particle number N, are determined self-consistently. We observe qualitatively different relaxation dynamics depending on the number of transition- energies in the few-level quantum system. In the case of a single transition-energy, we find that the whole system relaxes to a steady-state with different thermodynamic variables in the reservoirs. On the other hand, for more than one transition-energy, the whole system runs into a steady-state where both reservoirs have the same thermodynamic variables. Subsequently, linearizing the resulting equations enables us to characterize the equilibration process and its time scales in terms of equilibrium reservoir properties and linear response transport coefficients. Additionally, we investigate the use of such a device as particle transistor or particle capacitor and analyze its efficiency of performing chemical work form a heat flow between the reservoirs and the quantum system.

References

[1] C. Nietner, G. Schaller and T. Brandes, Phys. Rev. A **89**, 013605 (2014).

[2] F. Gallego-Marcos, C. Nietner, G. Schaller, G. Platero and T. Brandes, arXiv:1407.2804.

Dynamical symmetries and phase transitions in a three-spin system

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We consider the non-equilibrium dynamics of a simple system consisting of interacting spin-1/2 particles subjected to a collective damping [1]. The model is close to situations that can be engineered in hybrid electro/opto-mechanical settings. Making use of large-deviation theory [2], we find a GallavottiCohen symmetry in the dynamics of the system [3] as well as evidence for the coexistence of two dynamical phases with different activity levels. We show that additional damping processes smoothen out this behavior. Our analytical results are backed up by Monte Carlo simulations that reveal the nature of the trajectories contributing to the different dynamical phases.

References

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Reconfigurable long-range phonon dynamics in optomechanical arrays

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WORKING GROUP ADDRESSED: 3. IMPLEMENTATIONS

We investigate periodic optomechanical arrays as reconfigurable platforms for engineering the coupling between multiple mechanical and electromagnetic modes and for exploring many-body phonon dynamics. Exploiting structural resonances in the coupling between light fields and collective motional modes of the array, we show that tuneable effective long-range interactions between mechanical modes can be achieved. This paves the way towards the implementation of controlled phononic walks and heat transfer on densely-connected graphs as well as the coherent transfer of excitations between distant elements of optomechanical arrays.

References

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Program of the 3rd Working Group Meeting of Cost Action MP1209

18 August

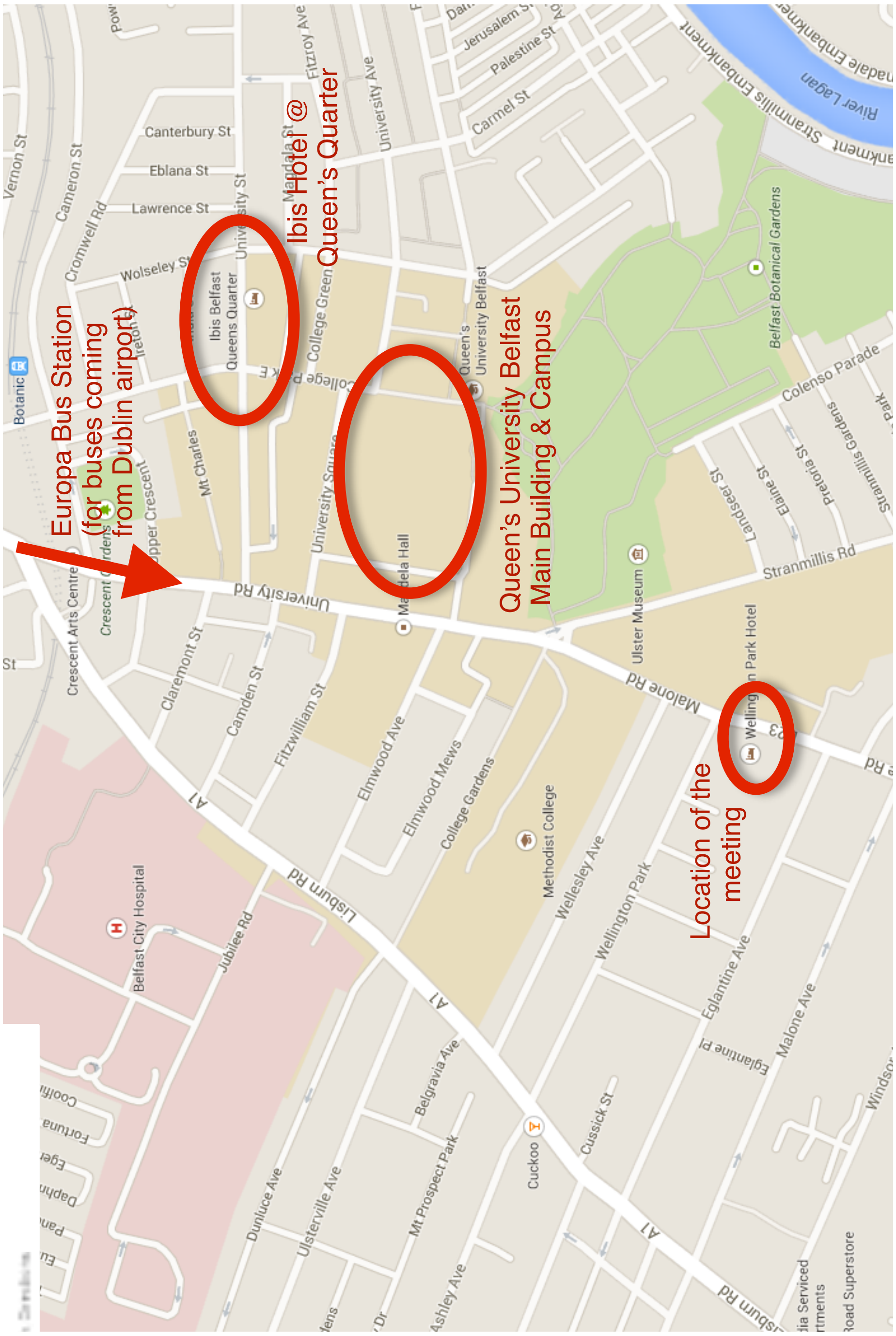
08:30--08:50	Registrations
08:50--09:00	Introduction
09:00--09:45	Ahsan Nazir
09:45--10:10	Maxime Clusel
10:10--10:25	Raam Uzdin
10:25--10:40	Mathis Friesdorf
10:40--11:05	Robert Whitney
11:05--13:05	Coffee & WGs discussions
13:05--14:30	Lunch
14:30--15:15	Lidia del Rio
15:15--15:30	Karen Hovhannisyan
15:30--15:55	John Goold
15:55--16:10	Felix Binder
16:10--16:35	James Millen
16:35--18:35	Coffee & WGs discussions based around posters

19 August

09:00--09:45	Ferdinand Schmidt-Kaler
09:45--10:15	Gabriele De Chiara
10:15--10:40	Laura Mancinska
10:40--10:55	Piotr Cwiklinski
10:55--11:20	Alberto Imparato
11:20--13:00	Coffee & WGs discussions
13:00--14:30	Lunch
14:30--15:15	Mikko Mottonen
15:15--15:30	Giovanni Vacanti
15:30--15:55	Lluis Masanes
15:55--16:10	Artur Malabarba
16:10--16:35	Francesco Plastina
16:35--18:35	Coffee & WGs discussions based around posters
19:00--	Social dinner

20 August

09:00--09:45	Antonio Acin
09:45--10:00	Philippe Faist
10:00--10:25	Tony Short
10:25--10:50	Tony J G Apollaro
10:50--11:05	Lea Kraemer
11:05--11:45	Coffee
11:45--12:10	Beatriz Olmos
12:10--12:25	Luis A. Correa
12:25--12:50	Nikolai Kiesel
12:50--13:05	Marco Pezzutto
13:05--14:45	Lunch
14:45--15:00	Closing remarks
	Free time for discussions & Departures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Queen's Quarter
Queen's University Belfast
Main Building & Campus
Location of the
meeting
Ibis Belfast
Queens Quarter
Mandela Hall
Queen's
University Belfast
Belfast Botanical Gardens
Ulster Museum
Methodist College
Belfast City Hospital
Crescent Arts Centre
Botanic
University Rd
Malone Rd
Stranmillis Rd
Lisburn Rd
A1
Canterbury St
Eblana St
Lawrence St
Wolseley St
Cromwell Rd
Cameron St
Vernon St
University St
College Green
College Park E
University Square
Mt Charles
Fitzroy Ave
University Ave
Carmel St
Palestine St
Jerusalem St
Stranmillis Embankment
River Lagan
Colenso Parade
Landseer St
Elaine St
Pretoria St
Stranmillis Gardens
Claremont St
Camden St
Fitzwilliam St
Elmwood Ave
Elmwood Mews
College Gardens
Wellesley Ave
Wellington Park
Eglantine Ave
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