Quantum Thermal Machines Workshop @ MPL Erlangen 2019

Time table, July 8-10

	Monday	**Tuesday**	**Wednesday**
09:45	Opening		
10:00	Ronnie Kosloff	Robert Alicki	Raam Uzdin
11:00	Coffee break	Coffee break	Coffee break
11:15	Wolfgang Niedenzu	Amikam Levy	Michele Campisi
11:45	Kilian Singer	David Gelbwaser-Klimovsky	Cyril Elouard
12:15	Özgür Müstecaplıoğlu	Alexandre Roulet	Luis Correa
12:30	Victor Mukherjee	Muddassar Rashid	Gabriel Landi
12:45	Lunch break	Lunch break	Lunch break
13:45	Ferdinand Schmidt-Kahler	Géraldine Haack	Open discussion
14:15	Fred Jendrzejewski	Giacomo Guarnieri	
14:45	Rafael Sanchez	Dario Poletti	
15:15	Coffee break	Coffee break	Sometimes it feels like the end of the world
15:45	Gernot Schaller	Eric Lutz	
16:15	Benjamin Stickler	Adolfo del Campo	
16:45	Nikolai Kiesel	Sai Vinjanampathy	
17:15	Poster session	Open discussion	
18:00	Dinner at MPL		
19:00	Film screening "Zeno Effect" by Dag Kaszlikowski	Conference dinner at Entla's Keller	
20:00		Scientific walk & talk	

Quantum Thermal Machines workshop @ MPL Erlangen 2019

Monday, July 8

9:45	Registration & Opening address
10:00	(45+15)min invited talk by Ronnie Kosloff ***Quantum Carnot Engine***
11:00	15min coffee break
11:15	(20+10)min invited talk by Wolfgang Niedenzu ***Concepts of work in autonomous quantum heat engines***
11:45	(20+10)min invited talk by Kilian Singer ***Single-atom heat engine***
12:15	(10+5)min talk by Özgür Müstecaplıoğlu ***Cooperative effects in quantum thermal machines***
12:30	(10+5)min talk by Victor Mukherjee ***Anti-Zeno quantum advantage in non-Markovian heat machines***
12:45	60min lunch break
13:45	(20+10)min invited talk by Ferdinand Schmidt-Kahler ***Experiments on thermodynamics with trapped ions***
14:15	(20+10)min invited talk by Fred Jendrzejewski ***TBA***
14:45	(20+10)min invited talk by Rafael Sanchez ***Non-equilibrium systems acting as demons***
15:15	30min coffee break
15:45	(20+10)min invited talk by Gernot Schaller ***Applications of the reaction-coordinate mapping in quantum thermodynamics***
16:15	(20+10)min invited talk by Benjamin Stickler ***Decoherence and thermalization of quantum rigid rotors***
16:45	(20+10)min invited talk by Nikolai Kiesel ***Thermodynamics with levitated nanoparticles***
17:15	Poster session
18:00	Buffet dinner at MPL
19:00	51min movie by Dagomir Kaszlikowski ***Zeno Effect*** Trailer & info at www.zenoeffectmovie.com

Tuesday, July 9

10:00	(45+15)min invited talk by Robert Alicki ***TBA***
11:00	15min coffee break
11:15	(20+10)min invited talk by Amikam Levy ***TBA***
11:45	(20+10)min invited talk by David Gelbwaser-Klimovsky ***TBA***
12:15	(10+5)min talk by Alexandre Roulet ***Revealing the Work Cost of Generalized Thermal Baths***
12:30	(10+5)min talk by Muddassar Rashid ***TBA***
12:45	60min lunch break
13:45	(20+10)min invited talk by Géraldine Haack ***TBA***
14:15	(20+10)min invited talk by Giacomo Guarnieri ***Thermodynamics of precision in quantum non equilibrium steady states***
14:45	(20+10)min invited talk by Dario Poletti ***Single atom energy-conversion device with a quantum load***
15:15	30min coffee break
15:45	(20+10)min invited talk by Eric Lutz ***Efficiency fluctuations of a quantum Otto engine***
16:15	(20+10)min invited talk by Adolfo del Campo ***Progress in engineering many-particle quantum thermal machines***
16:45	(20+10)min invited talk by Sai Vinjanampathy ***Synchronisation in Nanoscale Heat Engines***
17:15	Open discussion & walk to Entla's Keller
19:00	Conference dinner at Entla's Keller
20:00	Scientific walk & talk

Wednesday, July 10

10:00	(45+15)min invited talk by Raam Uzdin ***High-resolution thermodynamics and passivity deformations***
11:00	15min coffee break
11:15	(20+10)min invited talk by Michele Campisi ***TBA***
11:45	(20+10)min invited talk by Cyril Elouard ***An Interaction-Free Quantum Measurement-Driven Engine: Spooky work at a distance?***
12:15	(10+5)min talk by Luis Correa ***Pushing the limits of the reaction-coordinate mapping***
12:30	(10+5)min talk by Gabriel Landi ***Collisional Quantum Thermometry***
12:45	60min lunch break
13:45	Open discussion / last physicist standing
15:09	Sometimes it feels like the end of the world...

Poster session (Monday, 17:15 in the MPL foyer)

- Obinna Abah: ***Cost for controlling and speed of evolution of cascaded quantum systems dynamics***
- Jinfu Chen: ***TBA***
- Tobias Denzler: ***Fluctuations in an harmonic oscillator Otto engine***
- Moritz Göb: ***Transient Non-Confining Potentials for Speeding Up a Single Ion Heat Pump***
- Andreas Hartmann: ***Shortcuts to adiabaticity in many-body quantum heat engines***
- Michal Kolář: ***Measurement Induced Joining and Charging of Quantum Batteries***
- Yu-Han Ma: ***Optimal operating protocol to achieve efficiency at maximum power of heat engines***
- Lukas Martinetz: ***All-electrical cooling and control of levitated charged nanorotors***
- Henning Rudolph: ***Phase-locking of optically levitated nanoparticles***
- Björn Schrinski: ***Rotational friction and thermalization of quantum rigid rotors***

Abstracts

Luis Correa, University of Exeter

Pushing the limits of the reaction-coordinate mapping

The reaction-coordinate mapping is a useful technique to study complex quantum dissipative dynamics into structured environments. In essence, it aims to mimic the original problem by means of an 'augmented system', which includes a suitably chosen collective environmental coordinate---the 'reaction coordinate'. This composite then couples to a simpler 'residual reservoir' with short-lived correlations. If, in addition, the residual coupling is weak, a simple quantum master equation can be rigorously applied to the augmented system, and the solution of the original problem just follows from tracing out the reaction coordinate. But, what if the residual dissipation is strong? Here we consider an exactly solvable model for heat transport---a two-node linear "quantum wire" connecting two baths at different temperatures. We allow for a structured spectral density at the interface with one of the reservoirs and perform the reaction-coordinate mapping, writing a perturbative master equation for the augmented system. We find that: (a) strikingly, the stationary state of the original problem can be reproduced accurately by a weak-coupling treatment even when the residual dissipation on the augmented system is very strong; (b) the agreement holds throughout the entire dynamics under large residual dissipation in the overdamped regime; (c) and that such master equation can grossly overestimate the stationary heat current across the wire, even when its non-equilibrium steady state is captured faithfully. These observations can be crucial when using the reaction-coordinate mapping to study the largely unexplored strong-coupling regime in quantum thermodynamics.

Cyril Elouard, University of Rochester

An interaction-free quantum measurement-driven engine: spooky work at a distance?

Elitzur and Vaidman have proposed a setup that allows to detect the presence of a very sensitive bomb in one of the two arms of a single-photon interferometer seemingly without interacting with it [1]. We consider the case of the quantum bomb whose motional ground state is a superposition of being located inside and outside the first arm. When the so-called dark port detector fires, the presence of the bomb inside the first arm is confirmed, while logical inference dictates the photon, as not absorbed, must have taken the second arm. We show during such process, the bomb gains energy due to measurement-induced localization of its wave-function inside the arm. This energy is provided by the photon, despite a spatially local interaction Hamiltonian. Such a device allows to build a quantum engine similar to the one of Ref.[2], but extracting work in a seemingly non-local way. We analyze the weak values involved in the problem, and identify anomalous values, a hallmark of quantum contextuality. Indeed, depending on the choice of weak measurement basis, different histories about how the energy exchange takes place emerge. These results bring new insights in the notion of interaction-free measurement and how energy transfer can occur in the quantum world.

Giacomo Guarnieri, Trinity College Dublin

Thermodynamics of precision in quantum non equilibrium steady states

We investigate the fundamental trade-off between current fluctuations and entropy production for systems in non-equilibrium steady states (NESS). We use the technique of non-equilibrium statistical operators of McLennan / Zubarev form and illustrate how the entropy production can be expressed as a quantum relative entropy. Furthermore, by exploiting the geometry of the manifold of NESS states, we use parameter estimation in order to bound the co-variance of the currents in the NESS by the entropy production. Since our proof is geometrical, this fundamental result generalizes the thermodynamics of precision and the thermodynamic uncertainly beyond the classical Markovian paradigm. This result promises to evolve our understanding of the delicate relationship between fluctuations and quantum coherence in autonomous thermal machines.

Gabriel Landi, Universidade de Sao Paolo

Collisional quantum thermometry

We introduce a general framework for thermometry based on collisional models, where ancillas probe the temperature of the environment through an intermediary system. This allows for the generation of correlated ancillas even if they are initially independent. Using tools from parameter estimation theory, we show through a minimal qubit model that individual ancillas can already outperform the thermal Cramer-Rao bound. In addition, when probed collectively, these ancillas may exhibit superlinear scalings of the Fisher information, especially for weak system-ancilla interactions. Our approach sets forth the notion of metrology in a sequential interactions setting, and may inspire further advances in quantum thermometry.

Eric Lutz, University of Stuttgart

Efficiency fluctuations of a quantum Otto engine

We derive the probability distribution of the efficiency of a quantum Otto engine. We explicitly compute the quantum efficiency statistics for an analytically solvable two-level engine. We analyze the occurence of values of the stochastic efficiency above unity, in particular at infinity, in the nonadiabatic regime and further determine mean and variance in the case of adiabatic driving. We finally investigate the classical-to-quantum transition as the temperature is lowered.

Victor Mukherjee, IISER Berhampur

Anti-Zeno quantum advantage in non-Markovian heat machines

I will talk about fast-modulated cyclic quantum heat machines operating in the non-Markovian regime, which can lead to significant heat-current and power boosts induced by the anti-Zeno effect. Such boosts signify quantum advantage over generic heat-machines that operate in the conventional Markovian regime where the quantumness of the system-bath interaction plays no role. The present novel effect owes its origin to the time-energy uncertainty principle of quantum mechanics, which may result in enhanced system-bath energy exchange for modulation periods shorter than the bath correlation-time.

Dario Poletti, Singapore University of Technology and Design

Single atom energy-conversion device with a quantum load

We report on a quantum single atom energy-conversion device operating analogously to a classical engine, or refrigerator, and coupled to a quantum load. The "working fluid" consists of two optical levels while the load is one vibrational mode of the same ion, cooled down to the quantum regime. While our cycle is analogous to a classical thermodynamic cycle, our set-up allows us to explore two important differences with classical engines which are very relevant at the nanoscale: (i) the presence of a strong and generic coupling between engine and load which causes correlations between them;(ii) the use of non-thermal baths. We specifically examine the ergotropy of the load, which indicates the maximum amount of energy stored in the load that could be extracted with solely unitary processes. We show that ergotropy rises with the number of engine cycles despite an increase in the entropy of the load. Reference [1].

[1] N. Van Horne, D. Yum, T. Dutta, P. Hänggi, J. Gong, D. Poletti, M. Mukherjee, arxiv:1812.01303 (2018).

Alexandre Roulet, University of Basel

Revealing the Work Cost of Generalized Thermal Baths

Generalized thermal baths equilibrate the working medium they power to a unitarily-transformed thermal state. Theoretical predictions and experimental realizations have demonstrated that they allow to outperform the Carnot bound formulated in terms of the underlying thermal state, to induce an absorption refrigerator to operate for temperatures that would lead to heating, or even to extract work from a single bath.
Focusing on the primary aim of a more efficient use of energy with quantum machines, we address in this work[1] the fundamental question of whether these resources are worth the money. Specifically, we identify the work cost of employing any generalized thermal bath by exploiting the physical equivalence of quantum mechanics under unitary transforms. In other words, we perform a change of coordinates that reveals the work that is to be supplied on top of the heat exchange to engineer the coupling to the out-of-equilibrium bath of interest. The method is illustrated on an elementary heat engine that amplifies the field of a cavity out of a single bath. There, while the possibility of extracting work without the need for a second bath seems to provide a clear advantage, we find that the associated work investment actually exceeds the achieved amplification, with half of it being wasted by the heat machine.

[1] A.Roulet, Entropy 20, 973 (2018).

Gernot Schaller, TU Berlin

Applications of the reaction-coordinate mapping in quantum thermodynamics

The reaction-coordinate mapping has been introduced in the study of quantum systems coupled to a bosonic reservoir but it can equally well be applied to fermionic systems. It consists of identifying collective reservoir degrees of freedom and including them – at the level of the Hamiltonian – into the system. This effectively redefines the system-reservoir boundary, technically implemented by a transformation into a different frame.
In this transformed frame, simple master equation methods can be used to explore parameter regimes that are inaccessible with standard methods in the original frame. In

particular, this also allows to study particular strong-coupling or non-Markovian regimes with standard methods. Within the context of quantum thermodynamics, one can apply the reaction-coordinate mapping individually to every reservoir, which allows to investigate the performance of quantum heat engines – finite stroke or continuous – in the strong-coupling regime. For explicit feedback loops, it can be used to identify the thermodynamic cost of measurement and rate-control operations, which for example allows for a quantum treatment of Maxwell's demon.

I will present the basic idea of the mapping and review some of its implications for quantum heat engines.

• A. Nazir and G. Schaller, The reaction coordinate mapping in quantum thermodynamics, as a chapter of F. Binder, L. A. Correa, C. Gogolin, J. Anders, and G. Adesso (eds.), Thermodynamics in the quantum regime - Recent Progress and Outlook (Springer International Publishing), (2019) .

• G. Schaller, J. Cerrillo, G. Engelhardt, and P. Strasberg, Electronic Maxwell demon in the coherent strong-coupling regime, Physical Review B 97 , 195104 (2018) .

• S. Restrepo, J. Cerrillo, P. Strasberg, and G. Schaller, From quantum heat engines to laser cooling: Floquet theory beyond the Born-Markov approximation, New Journal of Physics 20 , 053063 (2018) .

• N. Martensen and G. Schaller, Transmission from reverse reaction coordinate mappings, The European Physical Journal B 92 , 30 (2019).

Sai Vinjanampathy, Indian Institute of Technology Bombay

Synchronisation in nanoscale heat engines

Owing to the ubiquity of synchronisation in the classical world, it is interesting to study it in the quantum regime. I will discuss synchronisation in classical and quantum systems. Furthermore, I will discuss how nanoscale heat engines are a natural platform to study quantum synchronisation. The ubiquitous physical phenomenon of synchronisation is related to the emerging field of quantum thermodynamics by the fact that quantum synchronisation is a mechanism of stable phase coherence. I will discuss the underlying principles that connect the fields and propose several directions for future study.