FM 58: Quantum Information Concepts in Thermodynamics

Time: Wednesday 14:00–16:00 Location: 3042

Invited Talk FM 58.1 Wed 14:00 3042

Thermodynamic uncertainty relations from exchange fluctuation theorems — •John Goold — Trinity College Dublin, Dublin, Ireland

Thermodynamic uncertainty relations (TURs) place strict bounds on the fluctuations of thermodynamic quantities in terms of the associated entropy production. In this work we identify the tightest (and saturable) matrix-valued TUR that can be derived from the exchange fluctuation theorems describing the statistics of heat and particle flow between multiple systems. Our result holds for both quantum and classical systems, undergoing general non-Markovian and non-stationary processes. Moreover, it provides bounds not only for the variances, but also for the correlations between thermodynamic quantities. To demonstrate the relevance of TURs to the design of nanoscale machines, we consider the operation of a two-qubit SWAP engine undergoing an Otto cycle and show how our results can be used to place strict bounds on the correlations between heat and work.

FM 58.2 Wed 14:30 3042

Coherence and catalysis in the Jaynes-Cummings model — •Anette Messinger, Atirach Ritboon, Frances Crimin, Sarah Croke, and Stephen M. Barnett — School of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, United Kingdom

Coherence is a crucial principle of quantum physics describing the difference between a quantum superposition and a classical statistical mixture. Like energy and entanglement, it can be described as a resource. In particular the creation of superposition in the energy basis and its impact on quantum thermodynamics received a lot of attention in recent years. It has been suggested that coherence can be created catalytically, that is without degrading the resource state which is used in the process [1]. This idea runs into difficulties, however, when taking correlations into account [2].

Here we study the repeated interaction of a cavity field initialized in a coherent state with a sequence of two-level atoms in the Jaynes-Cummings model and ask the question to what extent the production of atomic superposition states is catalytic in this setup. We investigate the degradation of coherence in the cavity during multiple rounds and show that the process is much more robust against failure than the original proposal of catalytic coherence [1] and correlations only have a small effect on the overall efficiency. We furthermore study the role of squeezing in the cavity and give an analytic expression for the ideal squeezing strength.

[1] Åberg, Phys. Rev. Lett. 113, 150402 (2014), [2] Vaccaro et al., J. Phys. A: Math. Theor. 51, 414008 (2018)

FM 58.3 Wed 14:45 3042

Von Neumann entropy from unitarity — Paul Boes[1], Jens Eisert[1], Rodrigo Gallego[1], Markus P. Müller[2,3], and •Henrik Wilming[4] — [1]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [2]Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Boltzmanngasse 3, A-1090 Vienna, Austria — [3]Perimeter Institute for Theoretical Physics, Waterloo, ON N2L 2Y5, Canada — [4]Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland

The von Neumann entropy is a key quantity in quantum information theory. It quantifies the amount of quantum information contained in a state when many identical and independent (i.i.d.) copies are available. We provide a new operational characterization of the von Neumann entropy which neither requires an i.i.d. limit nor any explicit randomness. We do so by showing that the von Neumann entropy fully characterizes single-shot state transitions in unitary quantum mechanics, as long as one has access to a suitable ancillary system whose reduced state remains invariant in the transition and an environment which has the effect of dephasing in an arbitrary preferred basis. Furthermore we formulate and provide evidence for the catalytic entropy conjecture, which states that the above holds true even in the absence of a decohering environment. If true, it would prove an intimate connection between single-shot state transitions in unitary quantum mechanics and the von Neumann entropy. We also discuss implications of these insights to thermodynamics.

FM 58.4 Wed 15:00 3042

Collective performance of a finite-time quantum Otto cycle — •Michal Kloc[1], Pavel Cejnar[2], and Gernot Schaller[3] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [2]Institute of Particle and Nuclear Physics, Faculty of Mathematics and Physics, Charles University, V Holešovičkách 2, Prague, 18000, Czech Republic — [3]Institut für Theoretische Physik, Technische Universität Berlin, D-10623 Berlin, Germany

We study the quantum Otto cycle where a collective spin system is used as the working fluid. Starting from a simple one-qubit system we analyze the transition to the limit cycle in the case of a finite-time thermalization. If the system consists of a large sample of independent qubits interacting coherently with the heat bath, the superradiant equilibration is observed. We show that this phenomenon can boost the power of the engine.

FM 58.5 Wed 15:15 3042

A truly quantum Szilárd demon — •Konstantin Beyer, Kimmo Luoma, and Walter T. Strunz — TU Dresden, Institut für Theoretische Physik

In a Szilárd engine the demon can extract work from a Gibbs state because she has knowledge about the actual microstate of the work medium. In quantum models of this gedankenexperiment the demon usually performs a quantum measurement on the system to obtain this necessary information.

In our approach we adopt a more global point view and consider a situation where the local Gibbs state arises from an entangled state between the work medium and its environment (eigenstate thermalization hypothesis). In such a bipartite situation a quantum demon who observes the environment can, in principle, exploit these correlations to help another party with the work extraction from the work medium. In particular, the possible work extraction schemes are manifold if the demons knowledge about the state of the system originates from an entangled state

Under suitable scenarios the average work extraction can be higher than what could be explained by any classical statistical model. This can be seen as the violation of a quantum steering task and, therefore, represents a semi-device-dependent test of quantumness. The asymmetry of a steering task reflects the typical partition into system and bath in many settings of quantum thermodynamics.

FM 58.6 Wed 15:30 3042

Quantum entropy flow is different — •Alwin van Steensel and Mohammad Ansari — Forschungszentrum Jülich, Jülich Aachen Reseach Alliance (JARA), Jülich, Germany

In quantum physics physical quantities are linear in density matrix, e.g. energy, current, spin, etc. However, this is not the case in quantum information theory as informational measures are nonlinear functions in density matrix; examples are entropy, fidelity loss, purity, etc. Is there any way to measure information in the lab using physical quantities? This is an important question that I will address in this talk. I will present a new correspondence between entropy and physical quantities and how it may introduce new physics.

References: [1] MH Ansari, Entropy production in a photovoltaic cell, Physical Review B 95 (17), 174302 (2017); [2] MH Ansari, YV Nazarov, Keldysh formalism for multiple parallel worlds, Journal of Experimental and Theoretical Physics 122 (3), 389-401 (2016); [3] MH Ansari, YV Nazarov, Exact correspondence between Renyi entropy flows and physical flows, Physical Review B 91 (17), 174307 (2015); [4] MH Ansari, YV Nazarov, Renyi entropy flows from quantum heat engines, Physical Review B 91 (10), 104303 (2015).

FM 58.7 Wed 15:45 3042

Energtic cost of quantum control protocol — •Obinna Abah — Queen's University Belfast, United Kingdom

We quantitatively assess the energetic cost of several well-known control protocols that achieve a finite time adiabatic dynamics, namely counterdiabatic and local counterdiabatic driving, optimal control, and inverse engineering. By employing a cost measure based on the norm of the total driving Hamiltonian, we show that a hierarchy of costs emerge that is dependent on the protocol duration. As case studies we explore the Landau- Zener model, quantum harmonic oscillator, and Jaynes-Cummings model and establish that qualitatively similar results hold in all cases. For the analytically tractable Landau-Zener case we further relate the effectiveness of a control protocol with the spectral features of the new driving Hamiltonians and show that in the case of counterdiabatic driving, it is possible to further minimize the cost by optimizing the ramp employed via Lagrange multipliers.