QI 29: Quantum Thermodynamics and Open Quantum Systems II

Time: Thursday 14:30–16:30 Location: B302

QI 29.1 Thu 14:30 B302

The role of generalized entropies in thermodynamics — •Bilal Cantürk — Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

Generalized entropies have direct consequences on the foundations of thermodynamics, statistical mechanics, information theory, and quantum thermodynamics [1]. Based on formal group theory, a generalized entropy so-called universal group entropy was proposed in [2] which covers some other generalized entropies as its special cases. In our studies [3,4] we investigated whether universal group entropy and its special cases satisfy some fundamental physically accessible conditions such as stability of the average value of the physical observables and the third law of thermodynamics. I will present our findings, their possible implications, and their compatibility with some recent studies [5]. References [1] Lostaglio, M. Rep. Prog. Phys. 82, 114001 (2019). [2] Tempesta, P. Ann.Phys. (N Y) 365, 180 (2016). [3] Canturk, B., et. al. Ann Phys (N Y) 377, 62 (2017). [4] Canturk, B., et. al. Int. J. Mod. Phys. B 32, 1850274 (2018). [5] Oikonomou, T., et. al. Phys. A: Stat. Mech. Appl. 578, 126126 (2021).

QI 29.2 Thu 14:45 B302

Correlations facilitate ergotropy transmission — •Rick Simon, Janet Anders, and Karen Hovhannisyan — University of Potsdam, Institut für Physik und Astronomie, 14476 Potsdam, Germany

Ergotropy quantifies the amount of unitarily extractable work stored in a system, and it is routinely used to measure the “charge level” of quantum batteries. A fundamental primitive in any (future) quantum power grid will be transmitting ergotropy from one system to another. Here we study energy-preserving unitary transmission channels for the case where both systems are qubits. More specifically, we take two noninteracting qubits and apply a joint unitary that commutes with the total Hamiltonian. When the initial state is factorized, we find that part of the transmitted ergotropy will necessarily be lost. However, the transmission can be lossless when the initial state is correlated. Moreover, despite the fact that no energy is injected into the total system during the transmission, the receiver may gain more ergotropy than is lost by the emitter. This extra gain is achieved at the expense of the correlations between the systems, which affects the reusability of the transmission channel. The degradability problem of the transmission-facilitating correlations is mitigated by the fact that these correlations need not be finely tuned. Indeed, by analyzing large sets of randomly sampled initial states, we found that, for a fixed (high enough) value of mutual information, most initial states incur no losses during ergotropy transmission.

QI 29.3 Thu 15:00 B302

Nonequilibrium quantum thermodynamics in open systems: the influence of initial correlations — •Alessandra Colla[1], Niklas Neubrand[1], and Heinz-Peter Breuer[1,2] — [1]Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

Finding a consistent formulation of quantum thermodynamics for general nonequilibrium processes is a fundamental and relevant question of recent research that has prompted the development of several proposals for the definition of basic thermodynamics quantities such as work, heat and entropy production. We have recently put forth one such approach (Phys. Rev. A 105, 052216) which relies on techniques of open quantum systems to determine an effective Hamiltonian as the operator for internal energy. The original formulation of the approach assumes factorizing initial conditions between the system of interest and the bath. We show here that the theory may be extended to any initial system-bath correlations with the important result that the effective Hamiltonian is unaffected by the presence of the initial correlations.

QI 29.4 Thu 15:15 B302

Long-time equilibration can determine transient thermality — •Karen Hovhannisyan[1], Somayyeh Nemati[1], Carsten Henkel[1], and Janet Anders[1,2] — [1]Institute of Physics and Astronomy, University of Potsdam, 14476 Potsdam, Germany — [2]Department of Physics and Astronomy, University of Exeter, Stocker Road, Exeter EX4 4QL, UK

When two initially thermal many-body systems start interacting strongly, their transient states quickly become non-Gibbsian, even if the systems eventually equilibrate. To see beyond this apparent lack of structure during the transient regime, we use a refined notion of thermality, which we call g-local. A system is g-locally thermal if the states of all its small subsystems are marginals of global thermal states. We numerically demonstrate for two harmonic lattices that whenever the total system equilibrates in the long run, each lattice remains g-locally thermal at all times, including the transient regime. This is true even when the lattices have long-range interactions within them. We compare our findings with the well-known two-temperature model. While its standard form is not valid beyond weak coupling, we show that at strong coupling it can be partially salvaged by adopting the concept of a g-local temperature.

QI 29.5 Thu 15:30 B302

power output, efficiency and role of the thermodynamic limit in nonequilibrium open quantum opto-mechanical engines — •Paulo José Paulino de Souza[1], Igor Lesanovsky[1,2], and Federico Carollo[1] — [1]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]School of Physics and Astronomy and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems,The University of Nottingham, Nottingham, NG7 2RD, United Kingdom

Cavity systems constitute a paradigmatic setting for optomechanical energy conversion. Experiments with atoms coupled to cavity modes are typically realized in nonequilibrium conditions, described by phenomenological models which cannot be derived via a weak system-bath coupling. This makes their interpretation as quantum engines challenging. Here, we present an effective, yet fully consistent, thermodynamic description for cavity-atom optomechanical systems, which exploits their nonequilibrium nature to achieve an energetic balance in terms of the persistent heat currents. To investigate the impact of collective behavior on their performance, we derive two thermodynamic limits, related to a weak and a strong optomechanical coupling, respectively. We illustrate our ideas focussing on a time-crystal quantum engine and discuss mechanical power generation, energy-conversion efficiency, and the emergence of metastable behavior in both limits.

QI 29.6 Thu 15:45 B302

A Rydberg ion quantum engine — •Wilson Martins[1], Igor Lesanovsky[1,2], and Federico Carollo[1] — [1]Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076Tübingen, Germany — [2]School of Physics and Astronomy and Centre for the Mathematics and Theoretical Physics of Quantum Non-Equilibrium Systems, The University of Nottingham, Nottingham,NG7 2RD, United Kingdom

We present and analyse a protocol for operating a quantum engine. Our engine is based on trapped laser-driven Rydberg ions, which constitute a quantum simulation platform where internal and external degrees of freedom can be controlled precisely. Our engine operates under out-of-equilibrium conditions in a setting where external laser-driving competes with dissipation and coherent interaction. We show that for a system of two trapped ions extractable work can be stored in the relative external motion of the trapped ions. We explore a driving protocol and quantify the stored work via the so-called ergotropy: the maximum amount of work that can be obtained from a quantum system.

QI 29.7 Thu 16:00 B302

Measurement feedback models of friction beyond the diffusive limit — •Michael Gaida and Stefan Nimmrichter — Universität Siegen, Deutschland

A typical approach to open quantum systems of motional degrees of freedom is often described in the limit of Brownian motion, which naturally arises from either weak coupling to thermal environments or from weak continuous monitoring.

Here we go beyond the diffusive description and provide a general Markovian measurement feedback model for friction: It involves randomly occur- ring POVM measurements of momentum combined with

unitary feedback operations. This enables us to describe arbitrary linear or nonlinear friction forces for quantum particles and quantum optomechanical systems.

For linear friction, we find that our model is equivalent to a random position measurement feedback process involving squeezing. Moreover, we highlight the connection to dissipative spontaneous collapse models.

QI 29.8 Thu 16:15 B302

Initial Correlations in Open Quantum Systems: Constructing Linear Dynamical Maps and Master Equations — •Niklas Neubrand[1], Alessandra Colla[1], and Heinz-Peter Breuer[1,2] — [1]Institute of Physics, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany — [2]EUCOR Centre for Quantum Science and Quantum Computing, University of Freiburg, Hermann-Herder-Straße 3, D-79104 Freiburg, Germany

We investigate the dynamics of open quantum systems which are initially correlated with their environment. Our strategy [1, 2] is to analyze how given, fixed initial correlations modify the evolution of the open system with respect to the corresponding uncorrelated dynamical behavior with the same fixed initial environmental state, described by a completely positive dynamical map. We show that, for any predetermined initial correlations, one can introduce a linear dynamical map on the space of operators of the open system which acts exactly like the proper dynamical map on the set of physical states and represents its unique linear extension. Furthermore, we demonstrate that this construction leads to a linear, time-local master equation with generalized Lindblad structure involving time-dependent, possibly negative transition rates. Finally, we illustrate the formalism with the Jaynes-Cummings model and consider the reduced dynamics of a two-level atom which is initially correlated with a single-mode radiation field.

[1] A. Colla, N. Neubrand, and H.-P. Breuer, New J. Phys., 2022
[2] N. Neubrand, Master Thesis, Uni Freiburg, 2022, DOI 10.6094/UNIFR/231431