DY 36: Stochastic Thermodynamics

Time: Wednesday 10:00–11:30 Location: ZEU 147

DY 36.1 Wed 10:00 ZEU 147

Operationally Accessible Bounds on Fluctuations and Entropy Production in Periodically Driven Systems — •Timur Koyuk and Udo Seifert — II. Institut für Theoretische Physik

For periodically driven systems, we derive a family of inequalities that relate entropy production with experimentally accessible data for the mean, its dependence on driving frequency, and the variance of a large class of observables [1]. With one of these relations, overall entropy production can be bounded by just observing the time spent in a set of states. Among further consequences, the thermodynamic efficiency both of isothermal cyclic engines like molecular motors under a periodic load and of cyclic heat engines can be bounded using experimental data without requiring knowledge of the specific interactions within the system. We illustrate these results for a driven three-level system and for a colloidal Stirling engine.

[1] T. Koyuk and U. Seifert, Phys.Rev.Lett.122, 230601(2019).

DY 36.2 Wed 10:15 ZEU 147

Stochastic thermodynamics of processes coupled to finite reservoirs — •Jonas Fritz, Basile Nguyen, and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, Stuttgart, Germany

Biomolecular processes are typically modeled using chemical reaction networks coupled to infinitely large chemical reservoirs. Through a chemical free energy difference between reservoirs, the system can be driven into a non-equilibrium steady state (NESS). In reality, cells are finite systems containing a finite number of molecules. In such systems, a NESS can be reached with the help of an externally driven pump. We introduce a simple model for finite-size chemical reservoirs with such a pumping mechanism. Crucial parameters then are the pumping rate and the size of the chemical reservoir. We apply this model to a simple biochemical oscillator, the Brusselator, and quantify the performance using the number of coherent oscillations. As a surprising result, we find that higher precision can be achieved with finite-size reservoirs, even though fluctuations there are larger.

DY 36.3 Wed 10:30 ZEU 147

Quantifying information for a stochastic particle in a flow-field — •Evelyn Tang[1] and Ramin Golestanian[1,2] — [1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany — [2]Rudolf Peierls Centre for Theoretical Physics, University of Oxford, United Kingdom

Quantification of information in small fluctuating systems has seen great theoretical progress recently, and been experimentally measured in a variety of systems from colloids and electrons to active and living matter. However, these questions have not been explored in flow-fields, which are ubiquitous in microfluidics, solid-state and biological systems. In the latter, such flows transport vital signalling molecules necessary for system function. We develop a general expression for the rate of change of information content in flow-fields to identify relevant contributions from both flow features and systems fluctuations. Further, we calculate the time evolution for particles in generic flow-fields, and use this to analyze the information content and residence time scale for various geometries and scenarios. For instance, this allows the identification of a mechanism for retaining a particle for longer times than diffusion. We identify the dependence of information content on various flow features and find the long time behavior of the change of information content and particle probability. Intriguingly, vorticity produces oscillations in the probability density but only enters the change of information content when there is an additional symmetric field component.

DY 36.4 Wed 10:45 ZEU 147

Stochastic thermodynamics of a sheared nanoclutch — •Sascha Gerloff and Sabine H. L. Klapp — Hardenbergstr. 36, D-10623 Berlin

Colloidal nanomachines convert optical-, electromagnetic-, acoustic- or chemical energy into *usefull* mechanical motion. Applications include colloidal microswimmers actuated by an external magnetic field [1] and sheared nanoclutches [2]. In the framework of stochastic thermodynamics, these nanomachines provide a powerful testing bed to explore this conversion of energy, which is related to the microscopic many-body dynamics of the colloids [3]. Following previous experimental studies [2], we focus on a sheared nanoclutch system, which consists of a circular, two-dimensional cluster of colloids that is confined between two rings and driven by optical- and magnetic fields. This system displays a complex non-linear mechanical response, characterized by shear-thinning, local shear-thickening and shear-banding. Performing (overdamped) Stokesian dynamics, we now turn to analyze the stochastic nature of the work and heat produced by this machine. In particular, we investigate how the many-body character of the non-equilibrium dynamics is reflected by the fluctuations of the thermodynamic quantities in the presence of hydrodynamic interactions.

[1] F. Martinez-Pedrero et al., *Phys. Rev. Lett.* **13**, 138301 (2015)
[2] A. Ortiz-Ambriz et al., *Soft Matter* **14**, 5121 (2018)
[3] S. Gerloff and S. H. L. Klapp, *Phys. Rev. E* **98**, 062619 (2018).

DY 36.5 Wed 11:00 ZEU 147

Affinity-dependent bound on the spectrum of stochastic matrices — •Matthias Uhl and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

Affinity has proven to be a useful tool for quantifying the non-equilibrium character of time continuous Markov processes since it serves as a measure for the breaking of time reversal symmetry. It has recently been conjectured that the number of coherent oscillations, which is given by the ratio of imaginary and real part of the first non-trivial eigenvalue of the corresponding master matrix, is constrained by the maximum cycle affinity present in the network. In this talk, we present a conjectured bound on the whole spectrum of these master matrices that constrains all eigenvalues in a fashion similar to the well known Perron-Frobenius theorem that is valid for any stochastic matrix. As in other studies that are based on affinity-dependent bounds, the limiting process that saturates the bound is given by the asymmetric random walk. For unicyclic networks, we prove that it is not possible to violate the bound by small perturbation of the asymmetric random walk and provide numerical evidence for its validity in randomly generated networks. The results are extended to multicyclic networks, backed up by numerical evidence provided by networks with randomly constructed topology and transition rates.

DY 36.6 Wed 11:15 ZEU 147

Non-reciprocal hidden degrees of freedom: an attempt to define entropy production in non-Markovian systems — •Sarah A. M. Loos, Simon M. Hermann, and Sabine H. L. Klapp — TU Berlin, Hardenbergstr. 36, 10623 Berlin

Real-world stochastic systems are often non-Markovian. This might be due to hydrodynamic backcoupling, viscoelastic effects, persistence in active swimmers, or an external feedback control loop acting on the system. Despite the omnipresence of memory, the incorporation of non-Markovian dynamics in the framework of stochastic thermodynamics is poorly understood [1,2]. In fact, fundamental problems remain, which are associated with the acausality of the backward process in the total entropy production functional. We discuss this crucial issue focusing on the case of discrete time delay, and show the implications of different approaches. As a first example, we review the outcome of a direct calculation on the basis of the acausal path integrals, which requires redefining the definition of entropy production, and, in fact, yields a functional which by construction cannot be calculated for any nonlinear system. Furthermore, we suggest a Markovian embedding approach [3]. While this strategy allows us to employ the standard formulae and is technically much simpler, it demands the interpretation of entropy production of auxiliary variables. For the case of a feedback controller, we offer an appropriate interpretation.

[1] Munakata, Rosinberg, PRL 112, 180601 (2014).
[2] Loos, Klapp, Sci. Rep. 9, 2491 (2019).
[3] Loos, Hermann, Klapp, preprint: arXiv:1910.08371 (2019).