# DY 11: Focus Session: Stochastic thermodynamics and information processing (joint session DY/BP)

Over the last 10 years, stochastic thermodynamics has been established as a conceptual framework for describing small driven systems that are embedded in a heat bath of well-defined temperature like biomolecular machines and transport through nano-structures. Describing measurement and subsequent feedback operations of such systems requires to merge concepts from information theory with thermodynamic ones taking into account the crucial role of fluctuations. This focus session highlights recent developments in this field in theory and experiment.

Time: Monday 15:00–17:45 Location: H44

**Invited Talk** DY 11.1 Mon 15:00 H44
**Large deviation functionals in stochastic thermodynamics** — •Andreas Engel, Johannes Hoppenau, and Daniel Nickelsen — Institut für Physik, Universität Oldenburg

The thermodynamic description of fluctuating systems is based on probability distributions for thermodynamic quantities like heat, work, and entropy. Unlike traditional statistical mechanics the tails of these distributions quantifying the frequency of rare, exceptional events are of particular interest. Large deviation theory is the proper mathematical framework to analyse these tails by introducing large deviation functions that characterize the probability of exponentially unlikely realizations.

A whole class of important large deviation functions deriving from a stationary stochastic process may be deduced from a single large deviation *functional* for its empirical density. For systems with detailed balance an explicit expression for this functional was derived in a series of mathematical papers by Donsker and Varadhan quite some time ago. We rederive their result using a path-integral approach and generalize it to non-equilibrium steady states. To this end the proper incorporation of the empirical probability current turns out to be crucial. We give explicit results for the large deviation functional, elucidate its connection with the entropy production and discuss the contraction to large deviation functions of more specific quantities.

**Invited Talk** DY 11.2 Mon 15:30 H44
**Thermodynamics with Continuous Information Flow** — •Massimiliano Esposito — University of Luxembourg, 162a avenue de la Faïencerie, L-1511 Luxembourg, Luxembourg.

A unified thermodynamic formalism describing information transfers in autonomous as well as nonautonomous systems described by stochastic thermodynamics will be presented. Information is continuously generated in an auxiliary system and then transferred to a relevant system that can utilize it to fuel otherwise impossible processes. Indeed, while the joint system satisfies the second law, the entropy balance for the relevant system is modified by an information term related to the mutual information rate between the two systems. This formalism will be applied to various model systems, including an electronic Maxwell demon.

Main reference: J. M. Horowitz and M. Esposito, "Thermodynamics with continuous information flow", Phys. Rev. X 4, 031015 (2014)

**Invited Talk** DY 11.3 Mon 16:00 H44
**Measuring energy and information one molecule at a time** — •Felix Ritort — Universitat de Barcelona, Barcelona (Spain)

I will present recent developments in the non-equilibrium physics of small systems by emphasizing single-molecule experiments and their contribution to expanding our current understanding of fundamental concepts, such as temperature, energy, entropy, and information.

**15 min. break**

**Invited Talk** DY 11.4 Mon 16:45 H44
**Information reservoirs, bipartite systems, and the minimal energetic cost of uncertainty in biomolecular reactions** — •Andre C Barato — Max Planck Institute for the Physics of Complex Systems

First, we show that the theory of stochastic thermodynamics can be generalized to include information reservoirs. These reservoirs can be seen as a sequence of bits that have their Shannon entropy changed due to the interaction with the system. Second, we discuss bipartite systems that can be used to study cellular information processing, allowing for the definition of an entropic rate that quantifies how much a cell learns about a fluctuating external environment. This entropic rate is bounded by the thermodynamic entropy production, which quantifies the rate of dissipated heat. Third, we show a thermodynamic uncertainty relation for biomolecular processes that connects the uncertainty in a random variable such as the output of a chemical reaction with the free energy that must be dissipated in order to sustain the chemical reaction. An uncertainty $\epsilon$ requires an energy dissipation of at least $2k_BT/\epsilon^2$.

**Invited Talk** DY 11.5 Mon 17:15 H44
**Feedback control of transport in nanostructures.** — •Tobias Brandes — TU Berlin, Institut für Theoretische Physik

I will discuss some models for transport through nanostructures from the point of view of thermodynamics and information. I start with a feedback-controlled stochastic process that works by mapping onto time-dependent (open-loop) control in an enlarged space of counting events [1], which has been experimentally realized very recently. Conceptually, with its infinite-bias limit this is somewhat outside the usual modified fluctuation-theorem paradigm, but a model of particle transport through a large number of channels can be partly used for the thermodynamic analysis [2]. In the Gaussian limit of this Kardar-Parisi-Zhang-like model, the dynamics can be interpreted as a simple diffusive spreading of a feedback signal across the channels that displays scaling. This can be quantified via the flow of information, and becomes visible, e.g., in the spectral function of the particle noise.

I will also present recent work on feedback control of a correlation function, i.e., the waiting time statistics of transport [3], including optimization ( with C. Emary) and an equivalent substitute ('hardwired') model for an analysis in terms of entropies.

[1] T. Brandes, Phys. Rev. Lett. 105, 060602 (2010). [2] T. Brandes, Phys. Rev. E 91, 052149 (2015). [3] T. Brandes, Ann. Phys. (Berlin) 17, No 7, 477-496 (2008).