DY 24: Stochastic Thermodynamics and Information Processing

Time: Wednesday 9:30–11:15 Location: H19

DY 24.1 Wed 9:30 H19

Optimising Energetics in Field Theories: Pareto Front and Phase Transitions — •Atul Tanaji Mohite and Etienne Fodor — University of Luxembourg, Department of Physics and Materials Science, L-1511, Luxembourg

Field theories have been extremely successful in characterizing the universal properties of various phase transitions, and in delineating a few canonical models which capture the essential Physics in a large class of systems. Interestingly, a generic framework for optimizing the energetic cost associated with the finite-time driving of such systems is still largely missing. Here, building on recent advances in stochastic thermodynamics and optimal transport theory, we show how to analytically derive the optimal driving protocols that minimise average stochastic work, which we apply to cases with either conserved or non-conserved scalar order parameter in the weak noise regime. Moreover, we formulate a numerical multi-optimization problem to simultaneously optimize the mean and fluctuations of stochastic work, leading to revealing a first-order phase transition in the corresponding Pareto front, which features the coexistence of multiple optimal protocols. Overall, our results elucidate how to drive field theories at a minimal energy cost, with the potential to be deployed to a broad class of systems.

DY 24.2 Wed 9:45 H19

Replica-Symmetry Breaking for Ulam's problem — •Phil Krabbe[1], Hendrik Schawe[2], and Alexander K. Hartmann[1] — [1]Institute of Physics, University of Oldenburg, Germany — [2]LPTM, CY Cergy Paris Université, France

For a given sequence $X = x_1, x_2, \ldots, x_n$ of numbers, an increasing subsequence (IS) is a subset of l elements $i(1) < i(2) < \ldots < i(l)$ such that $x_{i(1)} < x_{i(2)} < \ldots < x_{i(l)}$. The longest increasing subsequences (LIS) problem, i.e. to maximise l, was considered numerically first by S. Ulam and is a well studied topic. Here we consider the length l as an energy and study the canonical ensemble of ISs controlled by temperature parameter T, which includes the LIS for $T \to 0$. We extended our algorithm from [1] such that we can draw ISs in perfect equilibrium in polynomial time. This allows us to study large sequences with up to $n = 8192$ numbers.

We studied the IS numerically [2] for sequences X being permutations of integers. As measurable quantities, we analysed the mean energy, the specific heat C and and the overlap q between the drawn ISs. Our exact-sampling results indicate that the IS exhibits in the thermodynamic limit a complex energy landscape in the spirit of Replica Symmetry Breaking, characterised by a broad distribution $P(q)$ of overlaps and a hierarchical organization of the configuration space.

[1] P. Krabbe, H. Schawe and A.K. Hartmann, Phys. Rev. E **101**, 062109 (2020)
[2] A.K. Hartmann, *Big Practical Guide to Computer Simulations*, World Scientific (2015)

15 min. break

DY 24.3 Wed 10:15 H19

Optimality of nonconservative driving for finite-time processes with discrete states — •Benedikt Remlein and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

An optimal finite-time process drives a given initial distribution to a given final one in a given time at the lowest cost as quantified by total entropy production. We prove that for a system with discrete states this optimal process involves nonconservative driving, i.e., a genuine driving affinity, in contrast to the case of a system with continuous states. In a multicyclic network, the optimal driving affinity is bounded by the number of states within each cycle. If the driving affects forward and backwards rates nonsymmetrically, the bound additionally depends on a structural parameter characterizing this asymmetry [1].

[1] B. Remlein and U. Seifert, Phys. Rev. E 103, L050105 (2021)

DY 24.4 Wed 10:30 H19

Phase shift in periodically driven non-equilibrium systems: Its identification and a bound — •Julius Degünther, Timur Koyuk, and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

Time-dependently driven stochastic systems form a vast and manifold class of non-equilibrium systems used to model important applications on small length scales such as bit erasure protocols or microscopic heat engines. One property that unites all these quite different systems is some form of lag between the driving of the system and its response. For periodic steady states, we quantify this lag by introducing a generalized phase difference. We prove two tight bounds for this generalized phase difference, which provide upper limits to the lag such systems can yield. The first and most general bound depends only on the relative speed of the driving. The second more detailed bound takes additional information about the rates into account. We show that both bounds can be saturated by an appropriate choice of parameters.

DY 24.5 Wed 10:45 H19

Thermodynamic inference in partially accessible Markov networks: A unifying perspective from transition-based waiting time distributions — •Jann van der Meer, Benjamin Ertel, and Udo Seifert — II. Institut für Theoretische Physik, Universität Stuttgart, 70550 Stuttgart, Germany

The inference of thermodynamic quantities from the description of an only partially accessible physical system is a central challenge in stochastic thermodynamics. A common approach is coarse-graining, which maps the dynamics of such a system to a reduced effective one. While coarse-graining states of the system into compound ones is a well studied concept, recent evidence hints at a complementary description by considering observable transitions and waiting times. We consider waiting time distributions between two consecutive transitions of a partially observable Markov network and their ratios to quantify irreversibility and entropy production. We formulate criteria whether this entropy estimator provides a lower bound or recovers the full physical entropy production. Additionally, we derive estimators for the topology of the network, i.e., the presence of a hidden cycle, its number of states and its driving affinity. From a different perspective, our results can be condensed into a fluctuation theorem for an equivalent semi-Markov process. This mathematical perspective provides a unifying framework to compare our and known estimators. The correct version of time-reversal is crucial to clarify the relationship of formal versus physical irreversibility. Numerical calculations illustrate our exact results and estimate the quality of our bounds.

DY 24.6 Wed 11:00 H19

Geometric Brownian Information Engine — •Debasish Mondal, Rafna Rafeek, and Syed Yunus Ali — Department of Chemistry, Indian Institute of Technology Tirupati, Andhra Pradesh, India

We design a geometric Brownian information engine by considering over-damped Brownian particles inside a 2-D monolobal confinement with irregular width. Under such detention, particles experience an effective entropic potential which has a logarithmic form. We employ a feedback control protocol as an outcome of error-free position measurement. We reposition the centre of the confinement to the feedback site (x_f) instantaneously when the position of the trapped particle crosses the measurement distance (x_m) for the first time. Then, the particle is allowed to thermal relaxation. We find the exact analytical value of the upper bound of extractable work as $(\frac{5}{3} - 2ln2)k_BT$. We introduce a constant force G downwards to the transverse coordinate. G tunes the entropic contribution in the effective potential and hence the standard deviation (σ) of the probability distribution. The upper bound of the achievable work shows a cross-over from $(\frac{5}{3} - 2ln2)k_BT$ to $\frac{1}{2}k_BT$ when the system changes from an entropy dominated regime to energy dominated one. Compared to an energetic analogue, the loss of information during the relaxation process is higher in the entropy-dominated region, which accredits the less value in achievable work. We recognize that the extracted work is maximum when $x_f = 2x_m$ with $x_m \sim 0.6\sigma$, irrespective of the extent of the entropic limitation. The average displacement increases with growing entropic control and is maximum when $x_m \sim 0.81\sigma$.