DY 27: Statistical Physics far from Thermal Equilibrium - Part I

Time: Wednesday 9:30–12:15 Location: BH-N 334

Invited Talk DY 27.1 Wed 9:30 BH-N 334

On the use and abuse of thermodynamic entropy — •Peter Hänggi[1], Joern Dunkel[3], and Stefan Hilbert[2] — [1]Institute of Physics, University Augsburg, D-86135 Augsburg — [2]Exzellenzcluster Universe, Boltzmannstr. 2, D-85748 Garching — [3]Dept. Mathematics, MIT, 77 Massachusetts Avenue E17-412, Cambridge, MA 02139-4307 USA

Let us elaborate on the notion of thermodynamic entropy S (Clausius 1865) and its consequences. Gibbs put forward two notions of entropy for *isolated* systems that I commonly will refer to here as the volume entropy (involving the integrated density of states) and as the surface entropy, being proportional to the density of states, commonly also (incorrectly) known as the Boltzmann entropy. The absolute temperature, $T = \partial U/\partial S$, is related to thermodynamic entropy; but which one to use? – The consistency for thermodynamics, i.e. the validity for the celebrated 0-th, 1-st and 2-nd thermodynamic Law singles out the Gibbs-entropy [1].

I shall address shortcomings that relate to the thermodynamics of small systems when sticking to the (Boltzmann)-surface entropy [1-2]. This criticism applies also to the use of *absolute* negative temperatures in systems with an upper bound in energy, occurring in experiments in spin systems or experiments involving isolated ultra-cold atomic gases.

[1] S. Hilbert, P. Hänggi, and J. Dunkel, Thermodynamic Laws in Isolated Systems, Phys. Rev. E 90, 062116 (2014).

[2] J. Dunkel and S. Hilbert, Phase transitions in small systems: microcanonical vs. canonical ensembles, Physica A 370, 390 (2006).

DY 27.2 Wed 10:00 BH-N 334

Transverse waves discretize knot motion on a stretched polymer — •Raffaello Potestio[1] and Luca Tubiana[2] — [1]Max Planck Institute for Polymer Research, Mainz, Germany — [2]Josef Stefan Institute, Ljubljana, Slovenia

In recent years topological properties of polymers, in particular biopolymers such as proteins or DNA, have been investigated by means of computer simulations. At the same time, the capability of performing single molecule experiments has tremendously grown, allowing a direct verification of theoretical results. Most of the investigation effort, though, both from the theoretical as well as experimental point of view, has been focused on equilibrium properties. Now that technology allows one to reach unprecedented levels of time and space resolution, it would be of great interest to investigate the behavior of knotted polymers under non-equilibrium conditions.

In this talk I will present and discuss the numerical study of a model polymer, knotted and stretched, subject to forced oscillations. By varying the oscillation period of one extreme of the polymer, different dynamical phases are identified, characterized by varying diffusive behaviors of the knot. Specifically, a transition between a free diffusion state to a discretized jump dynamics is observed.

DY 27.3 Wed 10:15 BH-N 334

Equivalence of Non-Equilibrium Ensembles and Representation of Friction in Turbulent Flows: The Lorenz 96 Model — •Valerio Lucarini[1,2] and Giovanni Gallavotti[3] — [1]Institute of Meteorology, University of Hamburg, Hamburg, Germany — [2]Department of Mathematics and Statistics, University of Reading, Reading, UK — [3]Department of Physics, Sapienza University of Rome, Italy

We construct different equivalent non-equilibrium statistical ensembles in a simple yet instructive N-degrees of freedom model of atmospheric turbulence, introduced by Lorenz in 1996. We construct a modified version of the model where viscosity varies with time, in such a way that energy is conserved, and the resulting dynamics is fully time-reversible. The statistical properties of the irreversible and reversible model are in excellent agreement. The phase space contraction rate of the reversible model obeys the fluctuation relation. The equivalence between the two non-equilibrium ensembles extends to dynamical properties such as the Lyapunov exponents. These results have relevance in motivating the importance of the chaotic hypothesis, in explaining that we have the freedom to model non-equilibrium systems using different but equivalent approaches, and, in particular, that using a model of a fluid where viscosity is kept constant is just one option, and not necessarily the only option, for describing accurately its statistical and dynamical properties.

DY 27.4 Wed 10:30 BH-N 334

The Second Laws for an Information driven Current through a Spin Valve — •Philipp Strasberg[1], Gernot Schaller[1], Tobias Brandes[1], and Christopher Jarzynski[2] — [1]Institut für theoretische Physik, TU Berlin, Germany — [2]Institute for Physical Science and Technology, University of Maryland, USA

We propose a physically realizable Maxwell's demon device using a spin valve interacting unitarily for a short time with electrons placed on a tape of quantum dots, which is thermodynamically equivalent to the device introduced by Mandal and Jarzynski [PNAS 109, 11641 (2012)]. The model is exactly solvable and we show that it can be equivalently interpreted as a Brownian ratchet demon. We then consider a measurement based discrete feedback scheme, which produces identical system dynamics, but possesses a different second law inequality. We show that the second law for discrete feedback control can provide a smaller, equal or larger bound on the maximum extractable work as compared to the second law involving the tape of bits. Finally, we derive an effective master equation governing the system evolution for Poisson distributed bits on the tape (or measurement times respectively) and we show that its associated entropy production rate contains the same physical statement as the second law involving the tape of bits.

REF: arXiv:1407.7679

DY 27.5 Wed 10:45 BH-N 334

Josephson effect and coherent energy transport in classical nonlinear oscillators — Simone Borlenghi[1,2], •Stefano Iubini[3], Stefano Lepri[4], Lars Bergqvist[1], Anna Delin[1,2], and Jonas Fransson[2] — [1]Department of Material and Nano-Physics, School of Information and Communication Technology, KTH Royal Institute of Technology, Stocholm, Sweden — [2]Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden — [3]Centre de Biophysique Moléculaire (CBM), CNRS-UPR 4301 Rue Charles Sadron, F-45071 Orléans, France — [4]Istituto dei Sistemi Complessi, CNR Unità operativa di Firenze, Sesto Fiorentino, Italy

The standard approach to non-equilibrium thermodynamics describes transport in terms of generalised forces and coupled currents, a typical example being the Fourier law that relates temperature gradient to the heat flux. In this talk, we discuss the possibility to generate a persistent energy currents in a lattice of classical nonlinear oscillators with uniform temperature and chemical potential. In strong analogy with the well known Josephson effect, the currents are generated only by the phase differences between the oscillators. The phases play the role of additional thermodynamical forces, that drive the system out of equilibrium. Our results apply to a large class of oscillators and indicate novel ways to practically control the propagation of coupled currents and rectification effects in many different devices. They also suggest a simple, macroscopic setup for studying a phenomenon which hitherto have only been observed in microscopic, quantum-mechanical systems. (preprint arXiv:1411.5170)

15 min. break

DY 27.6 Wed 11:15 BH-N 334

Synchronization of moving oscillators — •Robert Grossmann[1], Fernando Peruani[2], and Markus Bär[1] — [1]Physikalisch-Technische Bundesanstalt, Abbestraße 2-12, 10587 Berlin, Germany — [2]Université Nice Sophia Antipolis, Laboratoire J.A. Dieudonné, UMR 7351 CNRS, Parc Valrose, F-06108 Nice Cedex 02, France

We consider an extension of the Kuramoto model of noisy phase oscillators with local interaction, where individual oscillators move randomly in D dimensional space. We study this model by using both analytical and numerical methods to answer the question how the synchronization is influenced by the motion of individual oscillators. Our model displays a non-equilibrium order-disorder transition from a desynchronized to a synchronized state depending on the noise acting on individual oscillators. The properties of the transition crucially depend on the spatial dimensionality and the diffusion-type of oscillators: We consider both normal diffusive motion as well as super-diffusively moving oscillators. We derive field equations which describe the large-scale dynamics of the system by means of Langevin equations for order pa-

rameters. By coarse-graining the model in this way, we are able to analyze the large-scale dynamics analytically. In particular, we study how fluctuations on the microscale (oscillator dynamics) enter the macroscopic dynamics (field theory) and calculate order-parameter correlation functions. Our theory suggests that a transition to long-range synchronization in $D \leq 2$ is not possible, if individual oscillators move diffusively. In contrast, long-range synchronization is possible in any spatial dimension for certain types of superdiffusive motion.

DY 27.7 Wed 11:30 BH-N 334

Condensation in asymmetric inclusion processes — •Markus F. Weber, Johannes Knebel, Torben Krüger, and Erwin Frey — Ludwig-Maximilians-Universität München

Condensation occurs when the entities of a system collectively concentrate in one or multiple states. In our work, we study such a phenomenon for jump processes on networks. In these processes, many particles may occupy a node and jump rates depend linearly on the occupation of departure and arrival nodes. These kinds of processes are thus referred to as inclusion processes - an example being the totally antisymmetric inclusion process (TASIP) - and reflect bosonic analogues of fermionic exclusion processes (e.g., the TASEP). Not only do inclusion processes describe the interaction of strategies in zero-sum games but they also govern chemical kinetics in autocatalytic reaction networks. Furthermore, they were recently used to show that driven-dissipative bosonic systems may condense into multiple quantum states. We derived an algebraic method to determine which of the nodes in an inclusion process become condensates. We show that the vanishing of relative entropy production guides these systems into non-equilibrium steady states in which detailed balance is broken. For inclusion processes on large random networks, we find that the interplay between critical properties of networks and dynamically stable network motifs determines the selection of condensates. Our methods allow for the design of network topologies and jump rates that result in condensates with oscillating occupation.

DY 27.8 Wed 11:45 BH-N 334

Feedback control of interacting transport channels — •Tobias Brandes — Institut für Theoretische Physik, TU Berlin

Understanding the flow of information is crucial for interpreting feedback control of stochastic processes. Quantitative tools are available in the form of modified fluctuation relations, mutual information and flows in the framework of stochastic thermodynamics for discrete or continuous degrees of freedom [1].

In this talk, I present an extension of a previous non-autonomous feedback model for transport of particles that was based on the synchronization with an external clock [2]. The new autonomous model can be viewed as a paradigm for interacting feedback mechanisms or feedback in networks [3], where the control is achieved in a collective manner.

[1] J. M. Horowitz, M. Esposito, Phys. Rev. X 4, 031015 (2014); A. E. Allahverdyan, D. Janzing, G. Mahler, J. Stat. Mech. P09011 (2009); D. Hartich, A. C. Barato, U. Seifert, J. Stat. Mech. P02016 (2014).

[2] T. Brandes, Phys. Rev. Lett. 105, 060602 (2010).

[3] S. Ito, T. Sagawa, Phys. Rev. Lett. 111, 180603 (2013).

DY 27.9 Wed 12:00 BH-N 334

Phase Behaviour of Active Swimmers in Depletants — •Benjamin Trefz[1,2], Subir Das[3], Sergei Egorov[4], Peter Virnau[2], and Kurt Binder[2] — [1]Graduate School Material Science in Mainz, Staudinger Weg 9, 55128 Mainz, Germany — [2]Johannes Gutenberg University Mainz, Department of Physics, Staudingerweg 7, 55128 Mainz, Germany — [3]Theoretical Sciences Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Jakkur P.O., Bangalore 560064, India — [4]Department of Chemistry, University of Virginia, Charlottesville, Virginia 22901, USA

We study the structure and phase behaviour of a binary mixture where one of the components is self-propelling in nature. The inter-particle interactions in the system were taken from the Asakura-Oosawa model, for colloid-polymer mixtures, for which the phase diagram is known. In the current model version the colloid particles were made active using the Vicsek model for self-propelling particles. The resultant active system was studied by molecular dynamics methods with a Langevin thermostat. The Vicsek model based activity facilitates phase separation, and is thus broadening the coexistence region. Our findings have been published recently in [1].

[1] Subir K. Das, Sergei A. Egorov, Benjamin Trefz, Peter Virnau, and Kurt Binder, Phys. Rev. Lett., "Phase Behavior of Active Swimmers in Depletants: Molecular Dynamics and Integral Equation Theory", 2014