DY 47: Statistical Physics: General I

Time: Thursday 9:30–12:30 Location: ZEU/0114

DY 47.1 Thu 9:30 ZEU/0114

Microcanonical ensemble out of equilibrium — •Roman Belousov[1], Jenna Elliott[1,2], Florian Berger[3], Lamberto Rondoni[4,5], and Anna Erzberger[1,2] — [1]European Molecular Biology Laboratory (EMBL), Heidelberg, Germany — [2]Heidelberg University, Heidelberg, Germany — [3]Utrecht University, Utrecht, The Netherlands — [4]Politecnico di Torino, Turin, Italy — [5]Istituto Nazionale di Fisica Nucleare (INFN), Turin, Italy

The microcanonical ensemble serves as the fundamental representation of equilibrium thermodynamics in statistical mechanics by counting all possible realizations of a system's states. Ensemble theory connects this idea with probability and information theory, leading to the notion of Shannon-Gibbs entropy and, ultimately, to the principle of maximum caliber describing *trajectories* of systems—in and out of equilibrium. While the latter phenomenological generalization reproduces many results of nonequilibrium thermodynamics, its physical justification remains an open area of research. What is the microscopic origin and physical interpretation of this variational approach? What guides the choice of relevant observables? We address these questions by extending Boltzmann's method to a microcanonical caliber principle. Thereby we systematically develop generalized local detailed-balance relations, clarify the statistical origins of inhomogeneous transport, and provide an independent derivation of key equations from stochastic thermodynamics. This approach introduces a *dynamical* ensemble theory, which we verify in numerical simulations of spatially extended, driven, and active systems.

DY 47.2 Thu 9:45 ZEU/0114

Ensemble dependence of the critical behavior of a system with long range interaction and quenched randomness — •Nir Schreiber, Reuven Cohen, and Simi Haber — Department of Mathematics, Bar Ilan University, Ramat Gan, Israel 5290002

A system with long range interaction (LRI) is usually non-additive. In other words, such a system with volume V and energy E, cannot be divided into two subsystems with energies E_1, E_2 , where $E = E_1 + E_2 + o(V)$.

The canonical and the microcanonical ensembles are expected to be equivalent when describing additive systems. Conversely, non-additivity may result in peculiar microcanonical phenomena that are not observed in the canonical ensemble, such as negative specific heat or the presence of microstates that are inaccessible to the system, leading to breaking of ergodicity.

The Blume-Emery-Griffiths (BEG) model with mean-field-like interaction is a simple example of a model with LRI. We employ that model to demonstrate inequivalence of the two ensembles, without interfering with the interaction content. Specifically, we consider a hybrid system governed by the BEG Hamiltonian, where the spins are randomly quenched such that some of them are "pure" Ising and the others admit the BEG states. It is found, by varying the concentration of the Ising spins while keeping the parameters of the Hamiltonian fixed, that the model displays different canonical and microcanonical phase portraits in concentration-temperature plain. Indications that these portraits are rich and rather unusual are provided.

DY 47.3 Thu 10:00 ZEU/0114

Quasicrystals with large rotational symmetries: Amorphous-like on small but ordered at large lengths scale — Alan Rodrigo Mendoza Sosa[1,2], Atahualpa S. Kraemer[1], Erdal C. Oğuz[2], and •Michael Schmiedeberg[3] — [1]Departamento de Física, Facultad de Ciencias, Universidad Nacional Autónoma de México, Ciudad Universitaria, 04510, Mexico City, Mexico — [2]Key Laboratory of Soft Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing, 100190, China — [3]Soft Matter Theory group, Institut für Theoretische Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

We study hyperuniformity in quasicrystals with large rotational symmetry. Hyperuniform systems are characterized by anomalously suppressed long-wavelength (i.e., large-length-scale) density fluctuations compared to those found in ordinary gases and fluids as well as in amorphous solids. We show that the degree to which the large-scale fluctuations are suppressed reveals a new characteristic length-scale. Below this length the patterns behave like amorphous systems while only above this length the long-ranged order becomes important leading to hyperuniformity in all cases.

DY 47.4 Thu 10:15 ZEU/0114

Emergence of mixed orientational ordering in quasi-one-dimensional superdisk and superball fluids — •Sakineh Mizani[1], Martin Oettel[1], Péter Gurin[2], and Szabolcs Varga[2] — [1]Institute for Applied Physics, University of Tübingen, Auf der Morgenstelle 10, 72076 Tübingen, Germany — [2]Physics Department, Centre for Natural Sciences, University of Pannonia, PO Box 158, Veszprém, H-8201 Hungary

We investigate the collective behavior of hard anisotropic particles confined in quasi-one-dimensional channels where particle centers are constrained to a line but particles can rotate freely. For superdisks and superballs with tunable curvature, equilibrium properties are calculated using an exact transfer-operator method. We reveal the emergence of a novel state of mixed orientational order which is characterized by a close-packing state with particles having two distinct orientations, distributed randomly over the line [1]. This ordering is highly sensitive to particle shape: small deviations from ideal spherical symmetry can stabilize or destabilize the mixed phase, demonstrating the the subtle interplay between particle geometry and confinement. Our results provide new insights into entropically driven ordering in confined systems, offering potential guidelines for designing colloidal assemblies and understanding phase behavior in narrow channels. [1] S. Mizani et al, arXiv:2510.06918, J. Mol. Liq. (accepted).

DY 47.5 Thu 10:30 ZEU/0114

Scaling of the Mpemba effect in the Ising model — •Janett Prehl and Martin Weigel — Institute of Physics, Technisch Universität Chemnitz, Chemnitz, Germany

The Mpemba effect – originally observed by Mpemba and Osborne for water [1] – describes the counterintuitive situation in which a hotter system relaxes faster than an initially colder one when both are instantaneously brought into contact with the same (cold) reservoir. Lately this phenomenon has been identified in various systems undergoing phase transitions [2 – 4]. Here, we investigate the Mpemba effect in the 2D Ising model with a critical temperature T_c. Using Monte Carlo simulations with different update dynamics, we study how initial temperatures and different initial magnetization influence the coarsening dynamics of different structural properties while quenching below T_c. In detail we investigate observables such as the energy per spin $\langle e \rangle$ and the average domain length $\langle \ell \rangle$. While Mpemba-like curve crossings appear for several conditions, they occur in the finite-size limited regime and weaken with increasing system size L. In contrast, non-zero initial magnetization enhances the effect, producing robust inversions in relaxation behavior.

[1] E. B. Mpemba and D. G. Osborn, *Phys. Educ.* **4** (1969) 172.
[2] M. Baity-Jesi et al., *PNAS* **116** (2019) 15350.
[3] N. Vadakkayil and S. K. Das, *Phys. Chem. Chem. Phys.* **23** (2021) 11186.
[4] A. K. Chatterjee, S. Takada, and H. Hayakawa, *Phys. Rev. Lett.* **131** (2023) 080402.

DY 47.6 Thu 10:45 ZEU/0114

Work extraction from a single negative-temperature bath considered as a temperature gradient-driven heat flow — •Wolfgang Bauer — Dept. of Internal Medicine I, Comprehensive Heart Failure Centre, UKW, Würzburg, Germany — EPV, Institute of Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany}

Work can dissipate as heat within a bath. The reverse, i.e. extracting work from a thermal bath without changing the state of the working system contradicts the 2nd law of thermodynamics. However, this does not hold for a bath at negative absolute temperature. Our approach reconciles the 2nd law with sole work extraction from a bath at negative temperature. We consider not only a single, but rather a large assembly of working systems. Within the assembly the working systems may exchange mutually energy by weak thermal coupling. This assembly is now assigned from Shannon entropy a canonical temperature. While this framework may seem unconventional for macroscopic working machines, it naturally becomes clear for very small, molecular-scale machines. We show for paradigmatic examples of working machines, that their initial canonical temperature is positive. Consequently, sole extraction of work from a bath at negative temperature represents simply heat flow from a hot system (bath at negative temperature) to a cool system (assembly of working machines), consistent with the 2nd law of thermodynamics.

15 min. break

DY 47.7 Thu 11:15 ZEU/0114

Advancing Stochastic 3-SAT Solvers by Dissipating Oversatisfied Constraints — •Joachim Schwardt[1,2] and Jan Budich[2,1] — [1]Max Planck Institute for the Physics of Complex Systems — [2]Institute of Theoretical Physics at TU Dresden

We introduce and benchmark a stochastic local search heuristic for the NP-complete satisfiability problem 3-SAT that drastically outperforms existing solvers in the notoriously difficult realm of critically hard instances. Our construction is based on the crucial observation that well established previous approaches such as WalkSAT are prone to get stuck in local minima that are distinguished from true solutions by a larger number of oversatisfied combinatorial constraints. To address this issue, the proposed algorithm, coined DOCSAT, dissipates oversatisfied constraints (DOC), i.e. reduces their unfavorable abundance so as to render them critical. We analyze and benchmark our algorithm on a randomly generated sample of hard but satisfiable 3-SAT instances with varying problem sizes up to N = 15000. Quite remarkably, we find that DOCSAT outperforms both WalkSAT and other well known algorithms including the complete solver Kissat. The essence of DOCSAT may be seen as a way of harnessing statistical structure beyond the primary cost function of a combinatorial problem to avoid or escape local minima traps in stochastic local search.

DY 47.8 Thu 11:30 ZEU/0114

Quest for optimal quantum resetting: Protocols for a particle on a chain — •Pallabi Chatterjee, S. Aravinda, and Ranjan Modak — Department of Physics, Indian Institute of Technology Tirupati, Tirupati 517619, India

In the classical context, it is well known that, sometimes, if a search does not find its target, it is better to start the process anew. This is known as resetting. The quantum counterpart of resetting also indicates speeding up the detection process by eliminating the dark states, i.e., situations in which the particle avoids detection. In this work, we introduce the most probable position resetting(MPR) protocol, in which, at a given resetting step, resets are done with certain probabilities to the set of possible peak positions that could occur because of the previous resets, followed by uninterrupted unitary evolution, irrespective of which path was taken by the particle in previous steps. In a tight-binding lattice model, there exists a twofold degeneracy (left and right) of the positions of maximum probability(peak). The survival probability with optimal restart rate approaches zero when the particle is reset with equal probability on both sides path independently. This protocol significantly reduces the optimal mean first-detected-passage time, and it performs better even if the detector is far apart compared to the usual resetting protocols in which the particle is brought back to the initial position. We propose a modified protocol, an adaptive two-stage MPR, by making the associated probabilities of going to the right and left a function of steps. We see a further reduction of the optimal mean FDT and improvement in the search process.

DY 47.9 Thu 11:45 ZEU/0114

Quantification of correlations by Fisher matrix — •Jakub Grabarczyk and Krzysztof Byczuk — Faculty of Physics, University of Warsaw, Poland

Quantum Fisher Information (QFI) is a concept based on relative entropy used to measure the distinctiveness of the given statistical ensemble. When applied to a lattice model, it quantifies the measurable difference between two instances of the model characterized by different parameter values. In my work, I demonstrate the significance of QFI in understanding microscopic properties of correlated quantum particles. The results are verified numerically. I compare the QFI across several important lattice models including the bosonic and fermionic Hubbard models as well as the Heisenberg model. Furthermore, I discuss how QFI relates to physically measurable quantities.

DY 47.10 Thu 12:00 ZEU/0114

Universal irreversibility—an information loss paradigm — •Jürgen Stockburger — Institut for Complex Quantum Systems, Ulm University

I develop a general prescription to incorporate irreversibility into any physical dynamics governed by a reversible microscopic dynamics with interactions. A description of irreversibility is introduced from the perspective that reversibility is *infeasible* due to insufficient means, not as a fundamental alteration of any microscopic theory.

With an arbitrary partitioning into subsystems, a coupled dynamics between a projected (decorrelated) and a residual (complementary) state is formulated, still fully equivalent to the reversible dynamics. All partitions are treated equally, without designation of "system" and "bath". With a (variable) truncation of the memory of the residual state, I recognize the fact that correlations in the distant past are undetectable in the present. The notion of irrecoverable correlation information is also implicit in current open-system approaches such as repeated interaction models [1]; the need to consider heat baths equally as a "system of interest" arises, e.g., in the context of quantum bolometry [2]. The framework of *entropy augmentation through subadditive excess* (EASE) introduces not only a universal view on irreversibility, it also provides a roadmap for actual computation [3].

[1] F. Ciccarello *et al.*, Phys. Rep. **954**, 1 (2022)
[2] B. Karimi *et al.*, Nat. Comm. **11**, 367 (2020)
[3] Stockburger, J.T., Eur. Phys. J. Spec. Top. (2025). `https://doi.org/10.1140/epjs/s11734-025-01923-2`

DY 47.11 Thu 12:15 ZEU/0114

Temperature as joules per bit — Charles Alexandre Bédard[1], •Sophie Berthelette[2], Xavier Coiteux-Roy[3], and Stefan Wolf[2,4] — [1]École de technologie supérieure, Montreal, Canada — [2]Università della Svizzera italiana, Lugano, Switzerland — [3]University of Calgary, Calgary, Canada — [4]Facoltà indipendente di Gandria, Gandria, Switzerland

In statistical mechanics, entropy is defined as a fundamental quantity. However, its unit, J/K, involves that of temperature, which is only subsequently defined — and defined in terms of entropy. This circularity arises with the introduction of Boltzmann's constant into the very expression of entropy. The J/K carried by the constant prevents entropy from finding a unit of its own while simultaneously obfuscating its informational nature. Following the precepts of information theory, we argue that entropy is well measured in bits and coincides with information capacity at thermodynamic equilibrium. Consequently, not only is the temperature of a system in equilibrium expressed in J/bit, but it acquires a clear meaning: It is the cost in energy to increase its information capacity by 1 bit. Viewing temperature as joules per bit uncovers the strong duality exhibited by Gibbs long ago between available capacity and free energy. It also simplifies Landauer's cost and clarifies that it is a cost of displacement, not of erasure. Replacing the kelvin with the bit as an SI unit would remove Boltzmann's constant from the seven defining constants.