DY 60: Critical Phenomena and Phase Transitions

Time: Friday 9:30–12:00 Location: ZEU/0114

DY 60.1 Fri 9:30 ZEU/0114

Noise-driven transitions and dynamic restoration in a two-state model under stochastic fields — •Raul Toral[1], Sara Oliver-Bonafoux[1], and Amitabha Chakrabarti[2] — [1]IFISC, Institute for Cross-disciplinary Physics and Complex Systems, UIB-CSIC, Palma de Mallorca, Spain — [2]Physics Department, Kansas State University, Manhattan, Kansas, USA

We study a two-state system influenced by both thermal fluctuations and stochastic external fields to explore how randomness affects non-equilibrium transitions and barrier-crossing dynamics. Using the Ising model in a heat bath as a minimal double-well prototype, we introduce spatially uniform, time-dependent random fields and analyze their impact on phase behavior.

The stochastic driving transforms the usual symmetry-breaking transition of the Ising model into a noise-induced transition between soft-paramagnetic and soft-ferromagnetic phases, where magnetization exhibits broad distributions and dynamical symmetry restoration between ferromagnetic states. For small field amplitudes, the transition coincides with the critical point of the undriven system, while at lower temperatures a genuine ferromagnetic phase emerges, marked by spontaneous state selection and diverging switching times.

These results reveal how stochastic forcing modifies phase behavior in bistable systems, providing new insights into noise-driven symmetry breaking and restoration.

DY 60.2 Fri 9:45 ZEU/0114

The frustrated Ising model on the honeycomb lattice: Metastability and universality — •Denis Gessert[1,2,3], Martin Weigel[3], and Wolfhard Janke[2] — [1]Centre for Fluid and Complex Systems, Coventry University, Coventry, CV1 5FB, United Kingdom — [2]nstitut für Theoretische Physik, Universität Leipzig, IPF 231101, 04081 Leipzig, Germany — [3]nstitut für Physik, Technische Universität Chemnitz, 09107 Chemnitz, Germany

We study the Ising model with competing ferromagnetic nearest- and antiferromagnetic next-nearest-neighbor interactions of strengths $J_1 > 0$ and $J_2 < 0$, respectively, on the honeycomb lattice. For $J_2 > -J_1/4$ it has a ferromagnetic ground state, and previous work has shown that at least for $J_2 \gtrsim -0.2J_1$ the transition is in the Ising universality class. For even lower J_2 some indicators pointing towards a first-order transition were reported. By utilizing population annealing Monte Carlo simulations together with a rejection-free and adaptive update, we can equilibrate systems with J_2 as low as $-0.23J_1$. By means of a finite-size scaling analysis we show that the system undergoes a second-order phase transition within the Ising universality class at least down to $J_2 = -0.23J_1$ and, most likely, for all $J_2 > -J_1/4$. As we show here, there exist very long-lived metastable states in this system explaining the first-order like behavior seen in only partially equilibrated systems.

DY 60.3 Fri 10:00 ZEU/0114

Hardness of the "swap" spin glass ensemble — •Alexander K. Hartmann[1], Leticia Cugliandolo[2], and Marco Tarzia[2] — [1]University of Oldenburg, Germany — [2]Sorbonne University, Paris, France

The “swap” ensemble [1] consist of spin glasses with quenched interaction constants J_{ij}, where the spins $s_i = \sigma_i\tau_i$ with $\sigma_i = \pm 1$ and $\tau_i \in [1-/\Delta/2, 1+\Delta/2]$ exhibit varying lengths τ_i. The value $\Delta = 0$ corresponds to the standard Ising case. Inspired by “swap moves” used for simulating structural classes [2], it was observed [1] that when including swaps $\tau_i \leftrightarrow \tau_j$ within Monte Carlo simulations at finite temperature with annealing $T \to 0$, ground states are easier to find. The actual “swap” ensemble samples consist of the bonds $\mathcal{J}_{ij} = J_{ij}\tau_i\tau_j$ obtained at the end of the annealing, respectively. Here, we study for two-dimensional spin glasses, by applying exact ground-state algorithms [3], the probability p_0 that true ground states have been found in the annealing. This allows us to define the hardness of the bond samples. In particular we consider the results as a function of the total number $t_{\rm MC}$ of annealing steps and length variation Δ. Furthermore, by applying domain-wall energy calculations [3], we investigate for various values of Δ and slow annealing ($p_0 \to 1$) whether the $\{\mathcal{J}_{ij}\}$ samples actually behave like spin glasses or rather like ferromagnets.

[1] A. Mirando, L. Cugliandolo and M. Tarzia, Phys. Rev. E **100**, L043301 (2024).
[2] L. Berthier and D. R. Reichman, Nat. Rev. Phys. **5**, 102 (2023).
[3] A.K. Hartmann and A.P. Young, Phys. Rev. B 64, 180404 (2001).

DY 60.4 Fri 10:15 ZEU/0114

Experimental study of dynamic phase transitions in nearly isotropic ferromagnetic films — Juan Marcos Marin Ramirez, Luciano Bravo, and •Andreas Berger — CIC nanoGUNE BRTA, E-20018 Donostia-San Sebastián, Spain

Non-equilibrium phase transitions occur across a wide range of physical systems. A relevant example is the dynamic phase transition (DPT) in ferromagnets, where the time-averaged magnetization Q, the dynamic order parameter, changes sharply under an oscillating field as its amplitude H_0 or period P vary. Hereby, it has also been observed that Q is dependent on the presence of an additional bias field H_b, which turns out to be the conjugate field of Q. Studies of the DPT have yielded important insights into dynamically ordered systems, their phase-space behaviour, and transient properties [1], yet this work has focused almost exclusively on Ising-type systems, restricting our understanding to a single material class [2]. Here, we experimentally investigate the DPT in polycrystalline Co films with very weak anisotropy. Dynamic magnetic states are monitored via real-time magneto-optical Kerr effect measurements across the relevant dynamic phase space. We find that the qualitative features of the dynamic phase diagram closely follow those of uniaxial Ising-type films. However, the metamagnetic anomalies of the paramagnetic dynamic state, ubiquitous in Ising-type films, appear to be significantly weaker in our nearly isotropic films.

[1] P. Riego et al., Phys. B Condens. Matter 549, 13 (2018). [2] M. Quintana and A. Berger, Phys. Rev. Lett. 131, 116701 (2023).

DY 60.5 Fri 10:30 ZEU/0114

Quadrupoling in ferroic materials — •Finja Tietjen and Richard Matthias Geilhufe — Chalmers University of Technology, Gothenburg, Sweden

Quadrupolar ordering has been investigated and characterized experimentally in different materials in recent years, but the theoretical approaches have only focused on special cases so far. We follow a new approach where we describe the quadrupoling as a composite order, arising from the fluctuations of a parent phase. This is in contrast to the conventional approach, where different phases are regarded as competing. We derive a mesoscopic field theory that includes thermal fluctuations. That enables us to find the anisotropy-dependent transition temperature and the free energy of the quadrupolar phase. We identify the phase transition into the quadrupolar phase as first-order and show that it is linked to a tetragonal distortion of the lattice of the material. With this framework, we correctly predict experimental measurements of the distortion in Ba2MgReO6 upon entering its quadrupole phase [1].

[1] D. Hirai, H. Sagayama, S. Gao, H. Ohsumi, G. Chen, T.-h. Arima, and Z. Hiroi, 'Detection of multipolar orders in the spin-orbit-coupled 5d Mott insulator Ba2MgReO6', Physical Review Research 2, 022063 (2020)

DY 60.6 Fri 10:45 ZEU/0114

Out-of-equilibrium intertwining of Landau and time-crystalline orders via collective excitations — •Andras Szabo[1] and Rama Chitra[2] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]ETH Zurich, Switzerland

The intertwining of multiple order parameters is a widespread phenomenon in equilibrium condensed matter systems, yet its exploration is often hindered by the complexity of real materials. Here, we present a controlled study of intertwined orders in a minimal and versatile driven-dissipative quantum-engineered platform. We consider a Bose-Einstein condensate at the intersection of two optical cavities, realizing two competing copies of a Z2 symmetry-breaking superradiant phase transition characterized by density wave orders. Using periodic drives that exploit dynamical symmetry reduction, we show that collective excitations can be harnessed to stabilize a variety of novel intertwined orders. Going beyond the conventional phenomenology involving Landau orders, we show the emergence of a larger class of out-of-equilibrium intertwined phases, including intertwining of purely time-crystalline orders, as well as between Landau and time crystal orders. These results should be observable in state of the art experimental setups

15 min. break

DY 60.7 Fri 11:15 ZEU/0114

Nucleation in the Vicinity of the Spinodal — •Sune Kühne and Marcus Müller — Universität Göttingen Institut für Theoretische Physik Friedrich-Hund-Platz 1 37077 Göttingen

Nucleation plays a central role in initiating phase separation across diverse soft-matter systems, from synthetic polymer blends to biomolecular condensates. Near the spinodal, Cahn-Hilliard nucleation theory (CHNT) predicts that the free-energy barrier vanishes while the size and material excess of the critical nucleus diverge. Forming a large cluster significantly delays nucleation even in the absence of a free-energy barrier in analogy to approaching the spinodal from the unstable region. Yet experiments consistently report a finite rate of phase separation even while crossing the spinodal, challenging the classical CHNT scenario. In this work, we investigate the onset of phase separation in the near-spinodal regime and reveal how thermal fluctuations qualitatively modify the nucleation pathway. Using Monte Carlo simulations, we show that fluctuations can locally and transiently push the system beyond the spinodal threshold, enabling the formation of nuclei on a finite length scale well below the system size. This mechanism produces finite nucleation times and naturally explains the experimentally observed smooth crossover from nucleation-dominated to spinodal-like dynamics. By analyzing the free-energy landscape as well as the structure and dynamics of the density fluctuations that eventually become critical, we identify the key physical principles governing phase selection in metastable mixtures.

DY 60.8 Fri 11:30 ZEU/0114

Self-Assembly as a Topological Entropic Transition: Geometry, Connectivity and the Emergence of Molecular Order — •Vicente Domínguez Arca — Biosystem and Bioprocesses Engineering, IIM-CSIC, Spain — Physical and Biophysical Chemistry, Bielefeld University, Germany

Self-assembly in soft-matter systems is traditionally explained through intermolecular forces acting at short metric ranges. Here we propose a radically different view: aggregation emerges from a topological-entropic transition in the geometry of accessible microstates. Using a connectivity-based model of amphiphilic micellization, we show that aggregation reduces the degeneracy of solvent configurations, collapsing a manifold of equivalent states into a confined thermodynamic paraboloid.

This reorganization generates effective forces without invoking pairwise attractions, as entropic gradients arise from the curvature of the configuration manifold itself. The hydrophobic effect thus appears not as a fundamental interaction, but as a solvent-mediated constraint that selects ordered states by maximizing accessible degrees of freedom. This framework explains micellization as a connectivity threshold and rationalizes enthalpy-entropy compensation as a geometric projection of the same curvature tensor. Self-assembly therefore emerges as a topological transition driven by entropy, revealing order as a consequence of state-space geometry rather than microscopic forces.

DY 60.9 Fri 11:45 ZEU/0114

On the adequate and stochastic structure of space in nature and phase transitions in the early universe — •Hans-Otto Carmesin — Universität Bremen, Fachbereich 1, Pf 330440, 28334 Bremen — Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — Gymn. Athenaeum, Harsefelder Str. 40, 21680 Stade

The problem to find an adequate coordinate system (ACS) has been proclaimed by the International Astronomical Union (IAU), and that problem has been solved here. This has far reaching consequences about the structure of space and time: The universal zero of the kinematic time difference δt_{kin} is derived. It corresponds to zero kinetic energy and to the minimum of relativistic energy at a given rest mass. Based on that finding, indivisible volume portions in nature are derived, and homogeneous space is identified as a stochastic average of these indivisible volume portions. With it, gravity and the quantum postulates have been derived. As a consequence, at high density, there occur dimensional phase transitions of space. In the very early universe, there occurred such high densities, and, as a consequence, the corresponding phase transitions took place. This explains the era of 'cosmic inflation', which turns out to be an era of cosmic unfolding.

Carmesin, H.-O. (2025): On the Dynamics of Time, Space and Quanta. Berlin: Verlag Dr. Köster.

Carmesin, H.-O. (2021): Quanta of Spacetime Explain Observations, Dark Energy, Graviton and Nonlocality. Berlin: Verlag Dr. Köster.