DY 7: Critical Phenomena and Phase Transitions

Time: Monday 11:30–13:00 Location: BH-N 128

Invited Talk DY 7.1 Mon 11:30 BH-N 128

Critical transitions in non-autonomous complex dynamical systems: theory and applications to ecosystems and climate — •Ulrike Feudel — ICBM, Carl von Ossietzky Universität Oldenburg, Germany

Many systems in nature are characterized by the coexistence of different stable states for a given set of environmental parameters and external forcing. Examples for such behavior can be found in different fields of science ranging from mechanical or chemical systems to ecosystem and climate dynamics. Perturbations, applied to those natural systems can lead to a critical transition from one stable state to another. Such critical transitions – also called tipping phenomena – can happen in various ways: (1) due to bifurcations, i.e. changes in the dynamics when external forcing or parameters are varied extremely slow (2) due to fluctuations which are always inevitable in natural systems, (3) due to shocks or extreme events, and (4) due to rate-induced transitions, i.e. when external forcing changes too fast compared to the ability of the forced system to follow the changes. We discuss these critical transitions and their characteristics and illustrate them with examples from mechanical and natural systems. Special emphasis is given to non-autonomous systems, in which we highlight the interplay between different time scales, like the dissipative time scale and the time scale of the variation of parameters or forcing. Moreover, we discuss the role of unstable states, that are not directly observable in nature, but nevertheless act as the organizing centers of the dynamics.

DY 7.2 Mon 12:00 BH-N 128

Critical fluctuations at finite-time dynamical phase transition — •Nalina Vadakkayil[1], Massimiliano Esposito[1], and Jan Meibohm[2] — [1]Complex Systems and Statistical Mechanics, Department of Physics and Materials Science, University of Luxembourg, L-1511 Luxembourg, Luxembourg — [2]Department of Mathematics, King's College London, London WC2R 2LS, United Kingdom and Technische Universität Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany

We explore the critical properties of the recently discovered finite-time dynamical phase transition in the non-equilibrium relaxation of Ising magnets. The transition is characterized by a sudden switch in the relaxation dynamics and it occurs at a sharp critical time. While previous works have focused either on mean-field interactions or on investigating the properties of the critical time, we analyse the critical fluctuations at the phase transition in the nearest-neighbor Ising model using Monte Carlo simulations. By means of a finite-size scaling analysis, we extract the critical exponents for the finite-time dynamical phase transition. In two spatial dimensions, these exponents turn out to be neither mean-field nor the same as at equilibrium. Instead, they seem to lie outside of the known universality classes, potentially representing a novel, non-equilibrium critical phenomenon.

DY 7.3 Mon 12:15 BH-N 128

Critical phase transitions through fractal-induced dynamics — •Fabio Salvati — Institute for Molecules and Materials, Radboud University, Heijendaalseweg 135, 6525 AJ Nijmegen, The Netherlands

In our study, we explore the dynamic characteristics of a single-particle system characterized by a non-trivial energy potential landscape, leading to a singular continuous energy spectrum. Typically, such a phase transition is achieved by introducing a periodic potential in the presence of a magnetic field, as described through the analysis of Almost Mathieu Operators. However, in our investigation, this unique phase transition emerges solely through geometric manipulations.

The geometric transformations we implement are tied to lattices of elementary shapes, such as squares and triangles, evolving into intricate fractal geometries like the Sierpinski carpet and gasket. Notably, these transformations manifest by projecting into the system's on-site potential, corresponding to the voids within the considered fractal structures.

Furthermore, we propose the possibility of experimentally validating our numerical findings, especially through the use of an ultracold gas setup.

DY 7.4 Mon 12:30 BH-N 128

Cubic fixed point in three dimensions: Monte Carlo simulations of the ϕ^4 model on the simple cubic lattice — •Martin Hasenbusch — Universität Heidelberg, Heidelberg, Deutschland

We study the cubic fixed point for $N = 3$ and 4 by using finite-size scaling applied to data obtained from Monte Carlo simulations of the N-component ϕ^4 model on the simple cubic lattice. We generalize the idea of improved models to a two-parameter family of models. The two-parameter space is scanned for the point, where the amplitudes of the two leading corrections to scaling vanish. To this end, a dimensionless quantity is introduced that monitors the breaking of the $O(N)$ invariance. For $N = 4$, we determine the correction exponents $\omega_1 = 0.763(24)$ and $\omega_2 = 0.082(5)$. In the case of $N = 3$, we obtain $Y_4 = 0.0142(6)$ for the renormalization group exponent of the cubic perturbation at the $O(3)$-invariant fixed point, while the correction exponent $\omega_2 = 0.0133(8)$ at the cubic fixed point. Simulations close to the improved point result in the estimates $\nu = 0.7202(7)$ and $\eta = 0.0371(2)$ of the critical exponents of the cubic fixed point for $N = 4$. For $N = 3$, at the cubic fixed point, the $O(3)$ symmetry is only mildly broken and the critical exponents differ only by little from those of the $O(3)$-invariant fixed point. We find $-0.00001 \leq \eta_{cubic} - \eta_{O(3)} \leq 0.00007$ and $\nu_{cubic} - \nu_{O(3)} = -0.00061(10)$.

DY 7.5 Mon 12:45 BH-N 128

Universal Approach to Critical Percolation — •Fabian Coupette and Tanja Schilling — Institute of Physics, University of Freiburg, Freiburg, Germany

Percolation is an archetypal critical phenomenon that occurs across a diverse range of contexts, such as the design of composite materials or vaccination strategies on community networks. In contrast to the critical exponents, the critical parameters (percolation threshold) characterizing the emergence of a system-spanning connected cluster, depend sensitively on the system properties. As a consequence, theoretical approaches predicting percolation thresholds are rare, often heuristic in nature, and tailored to specific applications.

We propose a general mapping of any kind of percolation problem onto a branching process which provides rigorous lower bounds for the percolation threshold. These bounds progressively tighten as we incorporate more local information into the description. We demonstrate our approach for different lattice and continuum problems obtaining accurate predictions with minimal effort. Our method is based on first principles, reproduces all exact solutions to percolation problems, and does not require fitting parameters. As such it offers an important theoretical reference in a field that is dominated by simulation studies and heuristic descriptions.