DY 49: Critical Phenomena and Phase Transitions

Time: Thursday 15:00–17:45 Location: ZEU 160

DY 49.1 Thu 15:00 ZEU 160

Metastate analysis for two-dimensional Ising spin glasses — •Alexander K. Hartmann[1] and A. Peter Young[2] — [1]University of Oldenburg, Germany — [2]University of California, Santa Cruz, USA

Spin glasses (SGs) are disordered magnetic systems which provide prototypical models for complex systems, including systems outside physics such as neural networks and machine-learning problems. For the two-dimensional (2d) case, exact numerical ground states (GSs) of large sizes can be obtained by polynomial-time graph-matching algorithms. Using these methods it was shown that 2d SGs exhibit a spin-glass ordered phase only at zero temperature, see e.g. [1]. Results from applying a modified version of the GS algorithm indicate that this phase is well described [2] by the so-called "droplet" theory, i.e., it has a simple structure. Here, we consider the *metastate* approach, which was introduced [3] to deal with the chaotic size-dependence of the spin-glass state. By studying a large range of sizes, we show convincingly that, in the thermodynamic limit, spin correlations in a local region are unaffected by the bonds far away, which is one of the main assumptions of the droplet picture.

[1] A.K. Hartmann and A.P. Young, Phys. Rev. B 64, 180404 (2001).
[2] A.K. Hartmann and M.A. Moore, Phys. Rev. Lett. 90, 127201 (2003).
[3] C.M. Newman and D.L. Stein, J. Phys.: Condens. Matter 15, R1319 (2003).

DY 49.2 Thu 15:15 ZEU 160

On the criticality of structurally disordered magnets — Maxym Dudka[1,2], Mariana Krasnytska[1,2,3], Juan Ruiz-Lorenzo[4,5], and •Yurij Holovatch[1,2,6] — [1]ICMP, NAS of Ukraine, Lviv, Ukraine — [2]L4 Collaboration Leipzig-Lorraine-Lviv-Coventry, Europe — [3]Université de Lorraine, Nancy, France — [4]Universidad de Extremadura, Badajoz, Spain — [5]BIFI, Zaragoza, Spain — [6]Coventry University, Coventry, UK

We discuss the problem of influence of structural disorder on criticality. As a case study, we consider an impact of a weak quenched disorder on a magnetic phase transition. Usually, such an impact is analyzed for a two-component mixture (e.g. a solid solution of a magnet with its non-magnetic counterpart). A distinct feature of our analysis is consideration of changes in the magnetic phase transition when both components are magnets. To this end, we make use of a generalized Ising model suggested recently [M. Krasnytska et al., J.Phys.: Complexity 1 (2020) 035008] in a context of complex systems. We apply the field theoretical renormalization group approach to analyze its effective and asymptotic critical behaviour. We show that this is the structural disorder itself that causes changes in the universal critical behaviour, regardless of whether it has a form of a random mixture of magnetic and non-magnetic constituents or of two different magnetic compounds [M. Dudka et al., arXiv:2207.13655].

DY 49.3 Thu 15:30 ZEU 160

Non-Hermitian PT-symmetric Ising spin chains: novel quantum phases and quantum phase transitions — •Grigory Starkov, Mikhail Fistul, and Ilya Eremin — Ruhr-Universität Bochum, Bochum, Germany

A theoretical study of quantum phases and quantum phase transitions occurring in non-Hermitian PT-symmetric transverse-field Ising spin model. A non-Hermitian part of the Hamiltonian is implemented via imaginary staggered longitudinal magnetic field corresponding to a local staggered gain and loss terms, γ.

Using a numerical diagonalization of the Hamiltonian for spin chains of a finite size N accompanied by a scaling procedure for the coherence length ξ, a complete quantum phase diagram γ-J (J is an adjacent spins interaction strength) is established. We obtain two quantum phases for J $<$ 0, i.e., PT-symmetry broken antiferromagnetic state and PT-symmetry preserved paramagnetic state, and the quantum phase transition line is the line of exception points. For J $>$ 0 the PT-symmetry of the ground state is retained in a whole region of parameter space of J and γ, and a system shows two intriguing quantum phase transitions between ferromagnetic and paramagnetic states for a fixed parameter $\gamma > 1$.

The qualitative quantum phase diagram is derived in the framework of the Bethe-Peierls approximation that is in a good accord with numerically obtained results. The quantum phase diagram can be verified in the microwave transmission experiments allowing to identify the transitions between the first excited and the ground states.

DY 49.4 Thu 15:45 ZEU 160

Predictive percolation: assessing fire connectivity in California — Olivia Hemond[1], •Diego Rybski[1,2,3], Ariani C. Wartenberg[1,4], Katherine J. Siegel[5], and Van Butsic[1] — [1]Department of Environmental Science, Policy, and Management, University of California, Berkeley, Berkeley, CA, United States — [2]Potsdam Institute for Climate Impact Research - PIK, Member of Leibniz Association, P.O. Box 601203, 14412 Potsdam, Germany — [3]Complexity Science Hub Vienna, Josefstädterstrasse 39, A-1090 Vienna, Austria — [4]Leibniz Centre for Agricultural Landscape Research, Eberswalder Str. 84, 15374 Müncheberg, Germany — [5]Department of Ecology & Evolutionary Biology, University of Colorado, Boulder, CO, USA

Damages from wildfire are increasing globally. Analyzing historical California fire data from 1950-2019, we propose a new method to estimate the percolation threshold, which represents statewide connectivity of fire-affected habitats. We create grid realizations of burnt areas over various time spans, measure the critical distances, and explore analogies with continuum percolation to predict the percolation threshold. Fires within our study period trend towards but do not yet reach percolation. We calculate the percolation threshold to be 45.8% of the state?s burnable area. Assuming fire patterns similar to the past seventy years, it would take 146.5 years, starting from 1950, to reach percolation across California. Within time periods shorter than 146 years, wildfire-affected areas are fragmented.

DY 49.5 Thu 16:00 ZEU 160

Determination of the nearest-neighbor interaction strength in VO2 via fractal dimension analysis — •Jacob Holder, Daniel Kazenwadel, Peter Nielaba, and Peter Baum — Universität Konstanz, Konstanz, Deutschland

The Ising model is one of the simplest and well-established models to simulate phase transformations in complex materials. However, its most central constant, the interaction strength J between two nearest neighbors, is not directly related to any macroscopic material property and is therefore hard to obtain. Here we report how to obtain this basic constant by a fractal dimension analysis of measured domain structures. In the example of VO_2, a strongly correlated material with first-order metal-to-insulator transition close to room temperature, we obtain an interaction strength of 11 meV. In a two dimensional simplification, we find an effective value of 17 meV due to the reduced number of nearest neighbors. These results link the fundamental constants in the Ising model to measured quantities of bulk materials.

15 min. break

DY 49.6 Thu 16:30 ZEU 160

Global Speed Limit for Finite-Time Dynamical Phase Transition in Nonequilibrium Relaxation — •Kristian Blom and Aljaz Godec — Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany

The nearest-neighbor interacting Ising model is a paradigm for classical many-body physics. Recent works unraveled an intriguing finite-time dynamical phase transition in the thermal relaxation of a mean field Curie-Weiss Ising model. This phase transition reflects a sudden switch in the dynamics, and manifests as a cusp in the probability density of magnetization. Its existence in systems with a finite range of interaction, however, remained unclear.

Employing the Bethe-Guggenheim approximation, which is exact on Bethe lattices, we demonstrate the finite-time dynamical phase transition in nearest-neighbor Ising systems for arbitrary quenches, including those within the two-phase coexisting region. Strikingly, for any given initial condition we prove and explain the existence of non-trivial speed limits for the dynamical phase transition and the relaxation of magnetization, which are absent in the mean field setting. Pair correlations, which are neglected in mean field theory, and trivial in the Curie-Weiss model, account for kinetic constraints due to frustrated local configurations, that give rise to a global speed limit.

Our findings may be relevant for optimizing ultrafast optical-switching ferromagnetic materials.

DY 49.7 Thu 16:45 ZEU 160

Crossover in the phase-coexistence between models with discrete and continuous variables — •Florian Kischel, Nils Caci, and Stefan Wessel — RWTH Aachen University, Aachen, Germany

The relative weight of the distinct phases that coexist at a first-order phase transition in systems with discrete degrees of freedom is well understood. For example, in the q-state Potts model, it is characterized by a ratio $R = 1 : q$ of the disordered vs. ordered regions. In models with continuous variables on the other hand, this ratio is generally unknown. Several recent instances however suggest that it equals $R = 1 : I_O$, where I_O denotes the integral measure of the space of extremal states of the ordered phase. In order to explore the emergence of this integral measure, we examine a system that realizes a crossover from discrete to continuous variables and study the behavior of R at its phase-coexistence points. In particular, we consider a generalized n-state clock-model on a three-dimensional simple cubic lattice with both bilinear and biquadratic exchange interactions. In the large-n (XY) limit, this model is known to harbor a first-order thermal phase transition, as does the 3-state Potts model, to which the model reduces in the limit of $n = 3$. Here, we explore the phase-coexistence over the range of intermediate values of n using large-scale Monte Carlo simulations.

DY 49.8 Thu 17:00 ZEU 160

Partition function zeros in the 3D Blume-Capel model — •Leïla Moueddene — Laboratoire de Physique et Chimie Théoriques, Université de Lorraine, Vandoeuvre-lès-Nancy, France

The phase diagram of the three-dimensionnal Blume Capel model shows an ordered ferromagnetic phase and a disordered paramagnetic phase, separated by a transition line from second order to first order at the tricritical point (TCP). The universality class of the second-order line is the Ising class, while the tricritical universality class governs the behaviour of the critical exponents at the tricritical point. It is well known that the upper critical dimension is $d_{uc} = 3$ at the TCP, thus Mean Field exponents are expected, modified by logarithmic correction factor. We determine analytically the logarithmic-correction exponents - also universal - using RG for ϕ_6 model. The knowledge of the partition function zeros is a quite fundamental and powerful approach to study a phase transition. While the Fisher zeros and Lee-Yang zeros are well known to study the thermal exponent y_t and magnetic exponent y_h, we build a new type of zeros from the complex plane of the crystal field which leads to the crystal exponent y_2: the crystal field zeros. We study the leading and logartihmic-corrections exponents numerically from the partition function zeros and compare with the analytical results, and check if the scaling relations are verified.

DY 49.9 Thu 17:15 ZEU 160

Boundary critical behavior of the three-dimensional O(N) universality class — •Francesco Parisen Toldin[1] and Max A. Metlitski[2] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

It was recently realized that the three-dimensional O(N) model exhibits an extraordinary surface universality class for a finite range of $N \geq 2$. We investigate the boundary critical behavior by means of high-precision Monte Carlo simulations of an improved model, where leading scaling corrections are suppressed. Contrary to simplified arguments on the bulk-surface phase diagram, and in line with a recent field-theoretical analysis, we find a special surface transition for $N = 3$, with unusual exponents, and an extraordinary phase with logarithmically decaying correlations. For a general N, the existence and universal properties of extraordinary phase are predicted to be controlled by certain amplitudes of the normal universality class, where one applies an explicit symmetry breaking field to the boundary. We extract these universal amplitudes by Monte Carlo simulations for $N = 2, 3$. Our results are in good agreement with direct Monte Carlo studies of the extraordinary universality class serving as a nontrivial quantitative check of the connection between the normal and extraordinary classes.

Ref.: F. Parisen Toldin, Phys. Rev. Lett. 126, 135701 (2021); F. Parisen Toldin, M. A. Metlitski, Phys. Rev. Lett. 128, 215701 (2022)

DY 49.10 Thu 17:30 ZEU 160

Critical phenomena in the two-dimensional dilute Baxter-Wu model — •Alexandros Vasilopoulos[1], Nikolaos G. Fytas[1], Michail Akritidis[1], and Martin Weigel[2] — [1]Centre for Fluid and Complex Systems, Coventry University, Coventry CV1 5FB, United Kingdom — [2]Institut für Physik, TU Chemnitz, 09107 Chemnitz, Germany

We study the question of universality in the two-dimensional spin-1 Baxter-Wu model in the presence of a crystal field Δ. We employ extensive numerical simulations consisting of various types, providing us with complementary results: Wang-Landau sampling at fixed values of Δ and a parallelized variant of the multicanonical approach performed at constant temperature T. A detailed finite-size scaling analysis in the regime of second-order phase transitions in the (Δ, T) phase diagram indicates that the transition belongs to the universality class of the four-state Potts model. Previous controversies with respect to the nature of the transition are discussed and attributed to the presence of strong finite-size effects, especially as one approaches the pentacritical point of the model. Lastly, to facilitate the study of $\Delta > 0$, where the two previous methods become increasingly inhibitory, a hybrid algorithm consisting of both a cluster and a single-spin-flip update was implemented and tested.