DY 22: Focus Session: Recent Progresses in Criticality in the Presence of Boundaries and Defects I (joint session DY/TT)

In recent years there has been a renewed interest in critical systems in the presence of boundaries or, more generally, defects. This attention is driven by different perspectives. Numerical studies of quantum spin models have reported in some cases unexpected boundary critical behavior. This, in turns, has led to a reconsideration of the classical surface critical behavior problem, with the discovery of so-far overlooked boundary phases. In this context, numerous recent studies have considered the so-called symmetry-protected topological gapless systems, and in particular their boundary states. At the same time, advances in conformal field theory, specifically the conformal bootstrap program, have addressed the problem of boundaries and defects in conformally-invariant theories. This Focus Session brings together some of the main actors in the aforementioned advancements in boundary critical phenomena.

Organized by Francesco Parisen Toldin (Aachen) and Stefan Wessel (Aachen)

Time: Wednesday 9:30–12:30 Location: A 151

Invited Talk DY 22.1 Wed 9:30 A 151

Boundary behavior at classical and quantum phase transitions — •Max Metlitski — Physics Department, MIT, Cambridge, MA, USA

There has been a lot of recent interest in the boundary behaviour of materials. This interest is driven in part by the field of topological states of quantum matter, where exotic protected boundary states are ubiquitous. In this talk, I'll ask: what happens at a boundary of a system, when the bulk goes through a phase transition. While this question was studied in the context of classical statistical mechanics in the 70s and 80s, basic aspects of the boundary phase diagram for the simplest classical phase transitions have been missed until recently. I'll describe progress in this field, as well as some extensions to quantum phase transitions.

DY 22.2 Wed 10:00 A 151

Universal results for near-critical systems in presence of defects — •Gesualdo Delfino — SISSA, Trieste, Italy

We show how low-energy singularities in field theory lead to exact universal predictions for near-critical systems in presence of defects and present the results for the order parameter profiles in three different cases: the three-dimensional XY model with boundary conditions producing a vortex line [1], the three-dimensional Ising model with boundary conditions leading to the formation of an interface [2], and the time evolution from domain wall initial conditions in quantum one-dimensional ferromagnets [3]. In the three cases, the theoretical predictions are successfully compared with numerical results.

References:

[1] Gesualdo Delfino, Walter Selke and Alessio Squarcini, Vortex mass in the three-dimensional O(2) scalar theory, Phys. Rev. Lett. 122 (2019) 050602

[2] Gesualdo Delfino, Walter Selke and Alessio Squarcini, Particles, string and interface in the three-dimensional Ising model, Nucl. Phys. B 958 (2020) 115139

[3] Gesualdo Delfino and Marianna Sorba, Space of initial conditions and universality in nonequilibrium quantum dynamics, Nucl. Phys. B 983 (2022) 115910

DY 22.3 Wed 10:15 A 151

Emergent geometry at the critical point — •Giacomo Gori — Heidelberg University

Critical correlations in a bounded system with ordered boundary are argued to be function of a suitably chosen metric g. This isotropic metric rules the order parameter profile according to general scaling arguments. These statements are verified via extensive Monte Carlo simulations. A natural candidate for g is the solution of a differential geometry problem known as Yamabe problem i.e. find a local rescaling of a metric making curvature constant. The correct Yamabe problem to be considered entails a fractional (anomalous in physics) generalization of the Ricci scalar curvature.

DY 22.4 Wed 10:30 A 151

Many-body correlations at wetting. Exact results — •Alessio Squarcini — Institute for Theoretical Physics, Innsbruck

The exact characterization of correlations in the presence of strongly fluctuating interfaces has always been considered a difficult problem in classical statistical mechanics. In this talk we present exact results for density correlations for an interface forming a droplet in two dimensions whose endpoints are pinned on a wall. Our framework, which hinges on recently developed field-theoretical techniques, applies to interfaces entropically repelled by a hard wall as well as to the regime of wetting transitions that we characterize also via the notion of interface structure factor in capillary wave theory. We will show that for entropically repelled interfaces the finite extent of the droplet yields finite-size corrections to correlation functions. These corrections are interpreted as adsorption of bubbles and self-interaction of the interface; their exact form is identified, interpreted in terms of Brownian excursions, and finally tested against high-precision Monte Carlo simulations in the absence of adjustable parameters. This analysis allows us to resolve a 40-years old discrepancy observed in early Monte Carlo studies. For the regime of wetting we present a recent conjectured expression for n-point correlation functions whose proof is a current work in progress.

A. Squarcini and A. Tinti, SciPost Phys. 15, 164 (2023). A. Squarcini and A. Tinti, Journal of High Energy Physics, 123 (2023). A. Squarcini and A. Tinti, J. Stat. Mech. (2023) 013206

DY 22.5 Wed 10:45 A 151

Emergent conformal boundaries from finite-entanglement scaling in matrix product states — •Rui-Zhen Huang — Department of Physics and Astronomy, University of Ghent, Belgium

The use of finite entanglement scaling with matrix product states (MPS) has become a crucial tool for studying 1+1d critical lattice theories, especially those with emergent conformal symmetry. We argue that finite entanglement introduces a relevant deformation in the critical theory. As a result, the bipartite entanglement Hamiltonian defined from the MPS can be understood as a boundary conformal field theory with a physical and an entanglement boundary. We are able to exploit the symmetry properties of the MPS to engineer the physical conformal boundary condition. The entanglement boundary, on the other hand, is related to the concrete lattice model and remains invariant under this relevant perturbation. Using critical lattice models described by the Ising, Potts, and free compact boson CFTs, we illustrate the influence of the symmetry and the relevant deformation on the conformal boundaries in the entanglement spectrum.

15 min. break

Invited Talk DY 22.6 Wed 11:15 A 151

Criticality senses topology — Oleg Vasilyev[2], •Anna Maciolek[1], and Siegfried Dietrich[2] — [1]Institute of Physical Chemistry Polish Academy of Sciences, Warsaw — [2]Max-Planck-Institute for Intelligent Systems, Stuttgart

It is well known that near the critical point, the behavior of a condensed matter system is characterized by the universality class. According to the concept of universality, the critical exponents governing the power law behavior of physical quantities, as well as the corresponding scaling functions, are the same within one universality class. In this lecture I will ask the question to what extent critical behavior "recognizes" the topology of the manifold supporting the critical system. This question is important because topological surfaces can either form spontaneously, such as vesicle membranes in biological systems, or they can be fabricated, such as Möbius rings, from microsized single crystals or from self-assembled chiral block copolymers. I will

talk about our recent research that tried to answer this question for Ising-like systems, using Monte Carlo simulations of the Ising model on finite two-dimensional manifolds with different topologies.

DY 22.7 Wed 11:45 A 151

Critical Casimir forces for quenched surface disorder in the 2d Ising model — Luca Cervellera and •Fred Hucht — Fakultät für Physik, Universität Duisburg-Essen

For the anisotropic square-lattice Ising model, the critical Casimir amplitude and force can be calculated exactly for many geometries and boundary conditions. From a recent exact solution for the cylinder with length L, circumference M, and with arbitrary quenched random boundary conditions at one boundary, we determine the full density of thermodynamic states $\omega(f^{(\mathrm{ex})}, m_{\mathrm{B}})$, with excess free energy per boundary spin $f^{(\mathrm{ex})}$ and boundary magnetization m_{B}, at criticality. From an analysis of this quantity we can derive the disorder averaged Casimir potential and Casimir force for different aspect ratios and disorder ensembles.

DY 22.8 Wed 12:00 A 151

Quantifying nonuniversal corner free energy contributions in weakly-anisotropic two-dimensional critical systems — •Florian Kischel and Stefan Wessel — RWTH Aachen University, Aachen, Germany

Confined two-dimensional critical systems with corners along the boundary of the spatial domain exhibit a logarithmic contribution to the free energy density. For conformal invariant bulk systems, this corner term has been derived by Cardy and Peschel in terms of the underlying central charge. However, for weakly anisotropic systems, the corner term deviates from this conformal field theory prediction, and the question arises, whether this anisotropy effect can be further quantified in a general way in terms of the asymptotic critical fluctuations. Here, we derive an exact formula for the corner free energy contribution of weakly-anisotropic two-dimensional critical systems in the Ising universality class on rectangular domains, expressed in terms of quantities that specify the anisotropic fluctuations. The resulting expression compares well to numerical exact calculations that we perform for the anisotropic triangular Ising model and quantifies the nonuniversality of the corner term for anisotropic critical two-dimensional systems. Our generic formula is exected to apply also to other weakly-anisotropic critical two-dimensional systems that allow for a conformal field theory description in the isotropic limit.

DY 22.9 Wed 12:15 A 151

Confinement of magnetic solitons and edge states in van-der Waals FeOCl — •Angela Möller[1], Martin Panthöfer[1], Stefanie Berinskat[1], Fabian Predelli[2], and Peter Lemmens[2] — [1]Dept. Chemistry, JGU Mainz, Mainz, Germany — [2]IPKM, TU Braunschweig, Braunschweig, Germany

In a comparative and systematic study of the isostructural van-der Waals materials ScOCl, ScOBr, FeOCl, the origin of unconventional magnetic properties of FeOCl has been investigated. Evidence for a size dependent order parameter and fluctuations are found in Mössbauer and Raman spectroscopy in conjunction with thermodynamic data and X-ray diffraction. We discuss our data in relation to soliton condensation into topological edge states.

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