TT 2: Quantum-Critical Phenomena (joint session TT/DY)

Time: Monday 9:30–12:30 Location: HSZ/0101

TT 2.1 Mon 9:30 HSZ/0101

Possible Quantum Criticality Tuned by Pressure in $CeVGe_3$ — Rong-Zhu Lin[1], Po-Yuan Cheng[1], Yusei Shimizu[2], Timothée Vasina[3], Daniel Braithwaite[3], Hanshang Jin[4], Peter Klavins[4], Valentin Taufour[4], and •Chien-Lung Huang[1] — [1]Department of Physics, National Cheng Kung University and Center for Quantum Frontiers of Research & Technology, Tainan 701, Taiwan — [2]International Research Center for Nuclear Materials Science, Institute for Materials Research (IMR-Oarai), Tohoku University, Ibaraki 311-1313, Japan — [3]Univ. Grenoble Alpes, CEA, Grenoble INP, IRIG, PHELIQS, 38000, Grenoble, France — [4]Department of Physics and Astronomy, University of California, Davis, California 95616, USA

In this work, we focus on the helical antiferromagnetic (AFM) $CeVGe_3$ to explore whether an AFM quantum critical point (QCP) can be approached. By performing resistivity measurements under pressure, we construct the pressure-temperature-field phase diagram and track the evolution of multiple field-induced phases. The AFM ordering temperature is suppressed at the critical pressure $p_c = 0.7$ GPa. The coefficient A in the temperature-dependent resistivity $\rho = \rho_0 + AT^2$ exhibits a maximum at p_c and gradually decreases at higher pressures, indicating enhanced electron-electron correlations near the critical point. These results reveal how the competition between Ruderman-Kittel-Kasuya-Yosida (RKKY) and Kondo interactions evolves under pressure, leading to a plausible pressure-induced QCP in $CeVGe_3$.

TT 2.2 Mon 9:45 HSZ/0101

Spin and charge criticality in the pseudogap two-impurity Anderson model — •Charlotte Beneke and Matthias Vojta — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

The Kondo effect originates from spin screening of localized impurities by conduction electrons. This Kondo screening can be suppressed by a fermionic bath following a pseudogap (i.e. power-law) density of states, by inter-impurity interactions, or by coupling to multiple conduction channels. We investigate the two-impurity Anderson model in various limits, and establish mappings to known Kondo and Anderson models. This leads to rich phase diagrams with Kondo-breakdown transitions of distinct universality classes giving rise to non-Fermi-liquid behavior. We analyze the phase diagram, and critical exponents of the pseudogap two-impurity Anderson model in the particle-hole symmetric, SU(2)-invariant case using perturbative renormalization-group techniques. We recover the transitions of the pseudogap single-impurity Anderson model, and find additional Kondo-breakdown quantum transitions to inter-impurity singlet-, triplet- and charge-ordered phases. At the quantum critical points, superconducting-pairing susceptibilities can be enhanced depending on the type of spin- and charge criticality. We discuss connections to heavy-fermion systems and two-quantum-dot realizations where quantum dots act as tunable magnetic impurities.

TT 2.3 Mon 10:00 HSZ/0101

Stability of Deconfined Quantum Critical Points Coupled to Quantum Phonons — •Anton Romen[1,2], Josef Willsher[1,2,3], David Hofmeier[4], Johannes Knolle[1,2,5], and Michael Knap[1,2] — [1]Technical University of Munich, Garching, Germany — [2]Munich Center for Quantum Science and Technology, München, Germany — [3]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [4]University of Southern Denmark, Odense M, Denmark — [5]Imperial College London, London, United Kingdom

Deconfined quantum criticality (DQC) describes continuous transitions beyond the Landau-Ginzburg paradigm. A typical example is the VBS-Néel transition in frustrated antiferromagnets. Since the VBS order parameter breaks lattice symmetries, it can couple to lattice distortions (phonons). Field-theory (PRB 110, 125130 (2024)) predicts that static lattice vibrations induce strong first-order character. A full quantum treatment, however, indicates that DQC survives above a critical phonon frequency. In this work, we provide a detailed study on the stability of 1D DQC under spin-phonon coupling resorting to a frustrated anisotropic J1-J2 model as a paradigmatic example. Using large-scale tensor network simulations, we determine the flow of the continuously varying critical exponents with phonon frequency and the critical phonon frequency, at which the transition becomes strongly first-order. By relating the critical theory to an Ashkin-Teller type model, we argue that the critical endpoint is in the four-state Potts universality class. We further compute dynamical phonon spectral functions that provide a powerful experimental signature of DQC.

TT 2.4 Mon 10:15 HSZ/0101

Inducing extraordinary-log criticality in the Heisenberg spin chain — •Grigorios Makris, Francesco Parisen Toldin, and Stefan Wessel — Institute for Theoretical Solid State Physics, RWTH Aachen University, Germany

We examine the ground state correlations emerging in a spin-1/2 Heisenberg chain upon coupling it to a quantum critical two-dimensional bilayer Heisenberg model. Based on the quantum-to-classical mapping and recent findings of unconventional surface criticality of three-dimensional classical Heisenberg models, extraordinary-log criticality is expected to become accessible within this setup along the coupled chain, which serves as a line defect. In particular, such a defect corresponds, through the quantum-to-classical mapping, to a planar defect in the classical case which exhibits extraordinary-log criticality. We use large-scale quantum Monte Carlo simulations to systematically explore this scenario, based on measurements of correlations and the spin stiffness, using the stochastic series expansion methods.

TT 2.5 Mon 10:30 HSZ/0101

Kibble-Zurek Dynamics in the Anisotropic Ising Model of the Si(001) Surface — •Gernot Schaller[1], Friedemann Queisser[1], Parya Katoorani[1], Christian Brand[2], Christian Kohlfürst[1], Mark Freeman[3], Alfred Hucht[2], Peter Kratzer[2], Björn Sothmann[2], Michael Horn-von Hoegen[2], and Ralf Schützhold[1,4] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]Fakultät für Physik, Universität Duisburg-Essen and CENIDE, Lotharstraße 1, 47057 Duisburg, Germany — [3]Department of Physics, University of Alberta, 4-181 Centennial Center for Interdisciplinary Science Edmonton, Alberta T6G 2E1, Canada — [4]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

As a simplified description of the nonequilibrium dynamics of buckled dimers on the Si(001) surface, we consider the anisotropic two-dimensional (2D) Ising model [1,2] and study the freezing of spatial correlations during a cooling quench across the critical point. Depending on the cooling rate, we observe a crossover from one-dimensional (1D) to 2D behavior [3]. For rapid cooling, we find effectively 1D behavior in the strongly coupled direction, for which we provide an exact analytic solution of the nonequilibrium dynamics. For slower cooling rates, we start to see 2D behavior where our numerical simulations show an approach to the usual Kibble-Zurek scaling in 2D.

[1] C. Brandt *et al.*, Phys. Rev. Lett. **130**, 126203 (2023).
[2] C. Brandt *et al.*, Phys. Rev. B **109**, 134104 (2024).
[3] G. Schaller *et al.*, Phys. Rev. Lett. **134**, 246202 (2025).

TT 2.6 Mon 10:45 HSZ/0101

Frustration effects and self-consistent matter description in the Dicke-Ising model on the sawtooth chain — •Jonas Leibig, Max Hörmann, Anja Langheld, Andreas Schellenberger, and Kai Phillip Schmidt — Department of Physics, Staudtstraße 7, Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany

We investigate how the exact thermodynamic-limit mapping of the Dicke-Ising model to a self-consistent effective matter Hamiltonian applies to the geometrically frustrated sawtooth chain. The mapping, established in Ref. [2], was recently solved with NLCE+DMRG for the unfrustrated chain in our work [1]. Using the same method, we obtain the zero-temperature phase diagram of the sawtooth geometry and identify frustration-induced features absent in the unfrustrated case. In the frustrated Ising limit, an infinitesimal effective transverse field lifts the classical degeneracy and produces a disorder-by-disorder transition, analogous to the transverse-field Ising model [3].

[1] J. Leibig, M. Hörmann, A. Langheld, A. Schellenberger, and K. P. Schmidt, *to be published* (2025).
[2] J. Román-Roche, Á. Gómez-León, F. Luis, and D. Zueco, *Physical Review B* **111**, 035156 (2025).
[3] D. J. Priour, M. P. Gelfand, and S. L. Sondhi, *Phys. Rev. B* **64**, 134424 (2001).

15 min. break

TT 2.7 Mon 11:15 HSZ/0101

Potts nematic quantum phase transition in Dirac fermion systems — •Max Fornoville[1,2], Kilian Fraboulet[1], Michael M. Scherer[3], and Laura Classen[1,2] — [1]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]School of Natural Sciences, Technische Universität München, 85748 Garching, Germany — [3]Theoretische Physik III, Ruhr-Universität Bochum, 44801 Bochum, Germany

With the advent of 2D moiré materials, Dirac fermion models have yet again emerged as promising candidates to describe putative quantum critical points in these systems. The presence of gapless fermions provides an avenue towards criticality beyond the conventional universality classes because it profoundly alters the quantum critical behavior, also giving rise to non-Fermi liquid behavior. We investigate the onset of nematic order in Dirac systems with hexagonal symmetry. Owing to the sixfold rotational symmetry, the nematic director selects among three equivalent orientations and the associated order parameter is described by a 3-state Potts model coupled to the Dirac fermions via a Yukawa interaction. In the ordered phase, the fermions remain gapless but the Dirac points split, dynamically breaking rotational symmetry. At the mean-field level, the transition is of first order, which we demonstrate using a minimal lattice model. We further employ a functional renormalization group approach to investigate the influence of the Dirac fermions on the Potts model and the nature of the transition due to a possible fermion-induced continuous quantum critical point.

TT 2.8 Mon 11:30 HSZ/0101

Chiral Quantum Phase Transition in Moiré Dirac Materials at finite density — •Ana Garcia-Page[1] and Laura Classen[1,2] — [1]Max-Planck-Institute for Solid State Research, Stuttgart, Germany — [2]Technical University of Munich, Munich, Germany

Chiral quantum phase transitions in Dirac materials at finite density: Strong enough interactions induce a semimetal-to-insulator transition in Dirac materials, which can be viewed as the solid-state analogue of the chiral phase transition in quantum chromodynamics. Moiré Dirac materials such as twisted bilayer graphene offer a new opportunity to study this transition because they facilitate tuning the effective interaction via a twist angle. Motivated by this, we explore the quantum phase transition of a (2+1) dimensional Dirac material at T = 0K which spontaneously develops a gap that breaks an Ising symmetry. It is still an open question what is the structure of the phase diagram at finite chemical potential. To explore it, we study a Gross-Neveu-Yukawa model for the phase transition using both a mean-field theory and a functional renormalization group approach. Interestingly, we find an intermediate state between semi-metal and insulator where a homogeneous solution appears to be unstable.

TT 2.9 Mon 11:45 HSZ/0101

Pseudo-first-order transition from competing Dirac masses in one dimension — •Manuel Weber — Institut für Theoretische Physik and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, Germany

Emergent symmetries and slow crossover phenomena are central themes in quantum criticality and manifest themselves in the pseudocritical scaling experienced in the context of deconfined criticality. Here we discover its conceptual counterpart, i.e., a symmetry-enhanced *pseudo-first-order transition*. It emerges from a one-dimensional realization of deconfined criticality between charge- and bond-ordered states driven by competing Holstein and Su-Schrieffer-Heeger electron-phonon couplings, for which quantum fluctuations and thereby the nature of the transition can be tuned systematically via the phonon frequency ω_0. In the classical limit $\omega_0 \to 0$, a low-energy Dirac theory predicts a direct first-order transition with emergent U(1) symmetry. Using exact quantum Monte Carlo simulations, we provide strong evidence for symmetry enhancement and even finite-size scaling on intermediate length scales but in the thermodynamic limit it turns into a narrow intermediate phase where both order parameters are finite, as chiral U(1) symmetry is weakly broken on the lattice. Including quantum lattice fluctuations diminishes the width of the intermediate phase, gradually restores the U(1) symmetry, and eventually tunes the system to a deconfined quantum critical point.

TT 2.10 Mon 12:00 HSZ/0101

Spectral Optimization of the 2-Sphere and Applications to Classical and Quantum Interacting Spin Systems — •Jonas Völler[1], Grigorios Makris[1], Fabian Hassler[2], and Stefan Wessel[1] — [1]Institute for Theoretical Physics, RWTH Aachen University, Germany — [2]Institute for Quantum Information, RWTH Aachen University, Germany

We investigate discretizations of the 2-sphere using non-uniform simplicial lattices. Starting from an icosahedral seed, we optimize the lattice by solving the free-particle tight-binding model and applying gradient descent to reduce spectral degeneracy breaking, with the goal of restoring the $2\ell + 1$-fold degeneracy of an $SO(3)$-symmetric system. We then perform Monte Carlo simulations of the critical Ising and Potts models and quantify the rotational symmetry breaking by projecting the two-point correlation function onto spherical harmonics. For sufficiently fine discretizations, we successfully recover the expected $SO(3)$-symmetric behavior. Finally, we carry out quantum Monte Carlo simulations of the transverse-field Ising model and locate its critical point by studying Binder-cumulant crossings.

TT 2.11 Mon 12:15 HSZ/0101

Hybrid Monte Carlo on the fuzzy sphere for conformal critical phenomena — •Lidia Stocker[1], Zheng Zhou[2], Yin-Chen He[3], Emilie Huffmann[4], and Johannes Stephan Hofmann[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Perimeter Institute for Theoretical Physics, Waterloo, Ontario N2L 2Y5, Canada — [3]C. N. Yang Institute for Theoretical Physics, Stony Brook University, Stony Brook, NY, USA — [4]Department of Physics, Wake Forest University, Winston-Salem, NC, USA

The fuzzy sphere regularization was recently introduced to study conformal symmetry in the 3D Ising transition [1]. Preliminary analysis with this approach showed excellent agreement with the state*operator correspondence, even though the size of the system considered was particularly restricted. Building on a sign-problem-free formulation of quantum many-body models on the fuzzy sphere [2], we extend the study to significantly larger system sizes using a hybrid Monte Carlo (HMC) scheme. In contrast to microscopic lattice models, we study the deconfined quantum critical point from a low-energy perspective and address whether the transition is of first- or second-order nature, assuming SO(5) symmetry. Our results demonstrate that HMC on the fuzzy sphere is a powerful and scalable framework for exploring conformal critical phenomena in models with many degrees of freedom.

[1] Phys. Rev. X 13, 021009 (2023)
[2] SciPost Phys. Core 7, 028 (2024)