TT 60: Quantum-Critical Phenomena (joint session TT/DY)

Time: Thursday 15:00–18:00 Location: H23

TT 60.1 Thu 15:00 H23

Superconductivity from the Condensation of Topological Defects in a Quantum Spin-Hall Insulator — Yuhai Liu[1], Zhenjiu Wang[2], Toshihiro Sato[2], Martin Hohenadler[2], Chong Wang[3], Wenan Guo[1], and •Fakher F. Assaad[2] — [1]Department of Physics, Beijing Normal University, Beijing 100875, China — [2]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [3]Perimeter Institute for Theoretical Physics, Waterloo, Ontario, Canada N2L 2Y5

The discovery that spin-orbit coupling can generate a new state of matter in the form of quantum spin-Hall (QSH) insulators has brought topology to the forefront of condensed matter physics. While QSH states from spin-orbit coupling can be fully understood in terms of band theory, fascinating many-body effects are expected if the state instead results from interaction-generated symmetry breaking. In particular, topological defects of the corresponding order parameter provide a route to exotic quantum phase transitions. Here, we introduce a model in which the condensation of skyrmion defects in an interaction-generated QSH insulator produces a superconducting (SC) phase. Because vortex excitations of the latter carry a spin-1/2 degree of freedom numbers, the SC order may be understood as emerging from a gapless spin liquid normal state. The QSH-SC transition is an example of a deconfined quantum critical point (DQCP), for which we provide an improved model with only a single length scale that is accessible to large-scale quantum Monte Carlo simulations.

TT 60.2 Thu 15:15 H23

Studies of Deconfined Quantum Criticality in a Half-filled Laudau Level — •Zhenjiu Wang[1], Matteo Matteo Ippoliti[2], Roger S. K Mong[3], and Michael P Zaletel[2,4] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany — [2]Department of Physics, Princeton University, Princeton, NJ 08544, USA — [3]Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, PA 15260, USA — [4]Department of Physics, University of California, Berkeley, CA 94720, USA

We perform Quantum Monte Carlo studies of deconfined quantum criticality (DQC) based on models of interacting fermions. As opposed to previous studies, this suggests an emergent SO(5) symmetry at criticality, our model has an exact SO(5) symmetry at the Hamiltonian level. This relies on the fact that our model is defined in the continuum. As opposed to lattice regularization, that would break the SO(5) symmetry, we follow a suggestion by [1], where the ultra-violet cutoff is realized by a magnetic field. Our model corresponds to 4 flavors of fermions with Hilbert space restricted to the zeroth Landau level (ZLL) of 8 component Dirac fermions as realized in Graphene, which maps to a nonlinear sigma model containing only bosonic degrees of freedom is studied, with the competition between the stiffness and an SO(5) Wess-Zumino-Witten topological term. AFQMC studies are free of the negative sign problem due to the existence of two anti-unitary particle-hole transformations that leaves the propagator invariant for each MC configuration.

[1] Ippoliti et al., arXiv:1810.00009 (2018)

TT 60.3 Thu 15:30 H23

Deconfined criticality from the QED3-Gross-Neveu model — •Lukas Janssen[1], Bernhard Ihrig[2], Luminita N. Mihaila[3], and Michael M. Scherer[2] — [1]Institut für Theoretische Physik, Technische Universität Dresden, Germany — [2]Institut für Theoretische Physik, Universität zu Köln, Germany — [3]Institut für Theoretische Physik, Universität Heidelberg, Germany

The QED_3-Gross-Neveu model is a (2+1)-dimensional U(1) gauge field theory involving Dirac fermions and a critical real scalar field. It has been argued that this theory represents a dual description of the deconfined quantum critical point between Néel and valence bond solid orders in frustrated quantum magnets. I will present evidence for a novel scaling relation that implies emergent SO(5) symmetry at criticality.

TT 60.4 Thu 15:45 H23

Deconfined quantum criticality in the two-dimensional Su-Schrieffer-Heeger model — •Stefan Beyl, Martin Hohenadler, Florian Goth, and Fakher F. Assaad — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Deutschland

The Su-Schrieffer-Heeger model is one of the most basic models for electron-phonon coupling. It captures the effects of fluctuating bond lengths—as described by quantum mechanical bond phonons—on the electronic hopping. While much work has been devoted to the one-dimensional case, systematic results in two dimensions are not available. Here, we present results from sign-free hybrid quantum Monte Carlo simulations at half-filling that support a deconfined quantum critical point between a valence bond solid and an antiferromagnet, as well as remarkable connections to an Ising lattice gauge theory with topologically ordered metallic and insulating phases.

TT 60.5 Thu 16:00 H23

Quantum Criticality near the Mott Transition — •Heike Eisenlohr[1], Seung-Sup B. Lee[2], Andreas Weichselbaum[2], and Matthias Vojta[1,3] — [1]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Physics Department, Arnold Sommerfeld Center for Theoretical Physics and Center for NanoScience, Ludwig-Maximilians-Universität München, Theresienstraße 37, 80333 München, Germany — [3]Center for Transport and Devices of Emergent Materials, Technische Universität Dresden, 01062 Dresden, Germany

The Mott metal-insulator transition is known to be a first order transition, with the transition line terminating in a classical critical end point at finite temperature Tc. Recent numerical studies of the half-filled Hubbard model, which employed dynamical mean-field theory and a quantum Monte Carlo impurity solver, and experiments in 2d organic salts have concordantly observed apparent quantum critical scaling of the resistivity in the regime T>Tc [1,2]. Although this conventionally indicates a nearby quantum critical point at T=0, the studied system shows only a classical first order transition at T=0. So far no theoretical explanation was able to identify the degrees of freedom which behave as if they were quantum critical, and why. To understand this unexpected scaling regime, we study the system with dynamical mean-field theory in combination with the numerical renormalization group.

TT 60.6 Thu 16:15 H23

Quantum critical behaviour in 2D Fermi systems with quadratic band touching — •Shouryya Ray, Matthias Vojta, and Lukas Janssen — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

We consider two-dimensional Fermi systems with quadratic band touching and C_3 symmetry, as realizable in Bernal-stacked honeycomb bilayers. Within a renormalization-group analysis, we demonstrate the existence of a quantum critical point at a finite value of the density-density interactions, separating a semimetallic disordered phase at weak coupling from a gapped ordered phase at strong coupling. The latter may be characterized by, for instance, antiferromagnetic, quantum anomalous Hall, or charge density wave order. In the semimetallic phase, each point of quadratic band touching splits into four Dirac cones as a consequence of the nontrivial interaction-induced self-energy correction, which we compute to the two-loop order. We show that the quantum critical point is in the $(2+1)$-dimensional Gross-Neveu universality class, characterized by emergent Lorentz invariance and a dynamic critical exponent $z = 1$. At finite temperatures, $T > 0$, we hence conjecture a crossover between $z = 2$ at intermediate T and $z = 1$ at low T, and construct the resulting nontrivial phase diagram as function of coupling strength and temperature.

15 min. break.

TT 60.7 Thu 16:45 H23

Quantum Criticality of an Ising-like Spin-1/2 Antiferromagnetic Chain in a Transverse Magnetic Field — •Zhe Wang[1], Thomas Lorenz[2], Denis Gorbunov[1], Pham Thanh Cong[1], Yoshimitsu Kohama[3], Sandra Niesen[2], Olivier Breunig[2], Johannes Engelmayer[2], Alexander Herman[2], Jianda Wu[4], Koichi Kindo[3], Joachim Wosnitza[1], Sergei Zherlitsyn[1], and Alois Loidl[5] — [1]Helmholtz Zentrum Dresden Rossendorf, Dresden, Germany — [2]University of Cologne, Cologne, Germany — [3]University of Tokyo, Kashiwa, Japan — [4]Tsung-Dao Lee Institute, Shanghai —

[5]University of Augsburg, Germany

We report on magnetization, sound velocity, and magnetocaloric-effect measurements of the Ising-like spin-1/2 antiferromagnetic chain system $BaCo_2V_2O_8$ as a function of temperature down to 1.3 K and applied transverse magnetic field up to 60 T [1]. At $B_\perp^c = 40$ T, the $T(B)$ curve shows a broad minimum, accompanied by a broad minimum in the sound velocity and a saturation-like magnetization. These features signal a quantum phase transition which is further characterized by the divergent behavior of the Grüneisen parameter $\Gamma_B \propto (B - B_\perp^c)^{-1}$. By contrast, around the critical field, the Grüneisen parameter converges as temperature decreases, pointing to a quantum critical point of the one-dimensional transverse-field Ising model [2].

[1] Zhe Wang et al., Phys. Rev. Lett. 120, 207205 (2018)
[2] Jianda Wu et al., Phys. Rev. B 97, 245127 (2018)

TT 60.8 Thu 17:00 H23

Phase diagram of SU(N) Dirac fermions on the π-flux lattice with a bond-bond interaction — •Johannes S Hofmann, Martin Hohenadler, and Fakher F Assaad — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

We use auxiliary-field quantum Monte Carlo simulations to study the phase diagram of SU(N) Dirac fermions with a bond-bond interaction V similar to Ref. [1] and an associated O($2N$) symmetry. In contrast to previous work, we consider a π-flux rather than a honeycomb lattice. The different coordination number is expected to favor antiferromagnetic (AFM) over valence bond solid (VBS) order. Accordingly, whereas AFM order is absent from the N-V phase diagram for $N > 2$ in Ref. [1], we find an AFM phase up to $N = 3$. Our results are consistent with Gross-Neveu semimetal-VBS transitions for $N > 1$ and deconfined VBS-AFM quantum critical points for $N = 2$ and $N = 3$.

[1] Z.-X. Li, Y.-F. Jiang, S.-K. Jian, and H. Yao, Nature Communications 8, 314 (2017)

TT 60.9 Thu 17:15 H23

Quantum criticality on a chiral ladder: a model study — Philipp Schmoll[1,2], •Andreas Haller[1,2], Matteo Rizzi[1], and Román Orús[1,3,4] — [1]Institute of Physics, Johannes Gutenberg University, 55099 Mainz, Germany — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany — [3]Donostia International Physics Center, Paseo Manuel de Lardizabal 4, E-20018 San Sebastián, Spain — [4]Ikerbasque Foundation for Science, Maria Diaz de Haro 3, E-48013 Bilbao, Spain

In our work we focus on exotic SU(2) invariant three-spin interactions which are exploited to engineer non-trivial helical phases in quasi one-dimensional ladder setups, also dubbed as wire deconstructionism. Such interactions are typically treated as a perturbation of the famous spin-1/2 Heisenberg model. Here, we extend the existing literature and tackle the non-perturbative low-energy regime by means of exact diagonalization, blockspin renormalization and bosonization. Our Luttinger Liquid (LL) analysis predicts a subtle gapping mechanism between two of the four helical modes in the ladder, which yields a critical model with central charge c=1. We support our analysis by numerical data obtained from an SU(2) symmetric implementation of the infinite Density Matrix Renormalization Group (iDMRG) algorithm.

TT 60.10 Thu 17:30 H23

Quantum criticality on a chiral ladder: an $SU(2)$ iDMRG study — •Philipp Schmoll[1,2], Andreas Haller[1,2], Matteo Rizzi[1], and Román Orús[1,3,4] — [1]Institute of Physics, Johannes Gutenberg University, 55099 Mainz, Germany — [2]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany — [3]Donostia International Physics Center, Paseo Manuel de Lardizabal 4, E-20018 San Sebastián, Spain — [4]Ikerbasque Foundation for Science, Maria Diaz de Haro 3, E-48013 Bilbao, Spain

We study the ground state properties of a ladder Hamiltonian with chiral $SU(2)$-invariant three-spin interactions, a possible first step towards the construction of truly two dimensional non-trivial systems with chiral properties starting from quasi-one dimensional ones. Extending our analysis by means of blockspin renormalization and bosonization we use a recent implementation of $SU(2)$ symmetry in the infinite Density Matrix Renormalization Group (iDMRG) algorithm. The numerical findings agree very well with the theoretical prediction of a gapless phase. In particular, the scaling of the entanglement entropy as well as finite-entanglement scaling data show that the ground state properties match those of the universality class of a $c = 1$ conformal field theory (CFT) in $(1 + 1)$ dimensions.

TT 60.11 Thu 17:45 H23

Statistically induced quantum phase-transitions in the extended Anyon-Hubbard model — •Martin Bonkhoff, Kevin Jägering, Shijie Hu, Imke Schneider, Axel Pelster, and Sebastian Eggert — Departement of Physics, University of Kaiserslautern, 67663 Kaiserslautern, Germany

Recently it has been shown that one-dimensional abelian anyons can be realized via density dependent Peierls-phases in bosonic models [1]. Furthermore extended interactions as well as a particle number constraint in bosonic Hubbard models can lead to a Symmetry-Protected-Topological (SPT) Haldane insulator phase [2]. We study the fate of SPT-order under statistical transmutation, and additionally observe a new gapped dimerized phase for attractive on-site interaction. By the technique of bosonization, we establish a unified low-energy field theory characterizing phases and relevant quantum phase transitions in the whole parameter region. We analyze the mechanism behind statistically induced phase transitions in combination with large-scale numerical simulations by the density-matrix renormalization group method.

[1] T. Keilmann, S. Lanzmich, I. McCulloch, and M. Roncaglia, Nat. Comm. 2, 361 (2011)
[2] E. Berg, E. G. D. Torre, T. Giamarchi, and E. Altman, Phys. Rev. B 77, 245119 (2008)