TT 35: Correlated Electrons: Quantum-Critical Phenomena - Theory

Time: Tuesday 14:00–15:45 Location: H21

TT 35.1 Tue 14:00 H21

Thermal phase transitions in the vicinity of the quantum critical point of spinless fermions on the honeycomb lattice — •Stephan Hesselmann and Stefan Wessel — Institute for Theoretical Solid State Physics, JARA-FIT, and JARA-HPC, RWTH Aachen University, 52056 Aachen, Germany

We consider spinless fermions on a honeycomb lattice (spinless $t-V$ model), which provide a minimal realization of lattice Dirac fermions. Nearest neighbor interactions drive a quantum phase transition from a semi-metallic phase to a charge ordered phase, which spontaneously breaks the chiral Z_2 symmetry of the Dirac fermions. The critical theory is given by the Gross-Neveu-Yukawa theory, which describes the process of mass generation due to the broken chiral symmetry. At finite temperature (and $V > V_c$) the quantum critical point connects to a line of second order thermal phase transitions that restore the broken chiral symmetry. We employ a recent sign-problem-free continuous time quantum Monte Carlo method [1, 2] to investigate the finite temperature phase diagram of the model. Furthermore we give estimates for the critical exponents of the Gross-Neveu chiral Ising universality class by studying the extension of the quantum critical regime to finite temperatures.

[1] E. F. Huffman et al., PRB **89**, 111101(R) (2014)
[2] L. Wang et al., New J. Phys. **16**, 103008 (2014)

TT 35.2 Tue 14:15 H21

Monte Carlo study of competing orders in a nearly antiferromagnetic metal — •Max Henner Gerlach[1], Yoni Schattner[2], Simon Trebst[1], and Erez Berg[2] — [1]Institute for Theoretical Physics, University of Cologne, Cologne, Germany — [2]Department of Condensed Matter Physics, Weizmann Institute of Science, Rehovot, Israel

We study the onset of antiferromagnetism in itinerant electron systems via a two-dimensional lattice model amenable to sign-problem-free determinantal quantum Monte Carlo simulations. These numerically exact simulations allow to precisely determine not only the boundaries of the magnetic phase, but also a dome-shaped d-wave superconducting phase near the putative antiferromagnetic quantum critical point. We discuss the entire phase diagram of this 2D model with regard to antiferromagnetic, superconducting, charge density wave, and pair density wave susceptibilities, as well as the superfluid density. We further find fluctuation diamagnetism well above the superconducting T_c and demonstrate where the electronic density of states displays the opening of a gap. Our results provide insights into the interplay of antiferromagnetism and unconventional superconductivity at intermediate to strong coupling.

TT 35.3 Tue 14:30 H21

Spin trimers coupled in 2D — •Dominik Strassel and Sebastian Eggert — Department of Physics and Research Center Optimas, University Kaiserslautern, 67663 Kaiserslautern, Germany

We study linear clusters of three strongly coupled $\mathcal{S} = \frac{1}{2}$ spins (trimers), which are weakly connected in a two dimensional lattice. For this we use Stochastic Series Expansion Quantum Monte Carlo simulations of the Heisenberg model in a magnetic field. These systems show a magnetization plateau at $\frac{1}{3}$ saturation, which is already known from strongly coupled three-leg ladders. In contrast to the frustrated triangular lattice which also shows a $\frac{1}{3}$ plateau, our systems do not suffer from the infamous minus sign problem. With increasing coupling between the trimers the plateau vanishes and a bi-critical point can be identified. To understand this in more detail we develop an effective two boson model describing these systems analytically, which allows us to calculate the behavior near the bi-critical point (e.g. magnetization).

TT 35.4 Tue 14:45 H21

Excitonic instability of three-dimensional gapless semiconductors with quadratic Fermi node — •Lukas Janssen[1,2] and Igor F. Herbut[2] — [1]Institut für Theoretische Physik, Technische Universität Dresden, Germany — [2]Department of Physics, Simon Fraser University, Burnaby, Canada

Three-dimensional gapless semiconductors with quadratic band touching, such as HgTe, α-Sn, or the pyrochlore iridate $Pr_2Ir_2O_7$, are believed to display a non-Fermi-liquid ground state due to long-range electron-electron interaction. I will argue that this state is inherently unstable towards spontaneous formation of a (topological) excitonic insulator. The instability can be parameterized by a critical fermion number N_c, in formal analogy to the problem of mass generation in (2+1)-dimensional quantum electrodynamics (QED_{2+1}). For $N < N_c$ the rotational symmetry is spontaneously broken, the system develops a gap in the spectrum, and features a finite nematic order parameter. To the leading order in the $1/N$ expansion and in the static approximation, the analogy with QED_{2+1} yields $N_c = 16/[3\pi(\pi-2)]$. Taking the important dynamical screening effects into account, we find that $N_c \geq 2.6(2)$, and therefore safely above the physical value of $N = 1$. I will also discuss results of recent complementary approaches to the problem using $2+\epsilon$ expansion and functional renormalization group, respectively, which turn out to arrive at a similar conclusion. Some experimental consequences of the nematic ground state will be pointed out.

[1] L. Janssen and I. F. Herbut, arXiv:1509.01737 [cond-mat.str-el]

TT 35.5 Tue 15:00 H21

Violation of hyperscaling at the Ising-nematic quantum critical point in a two-dimensional metal — •Andreas Eberlein[1], Ipsita Mandal[2], and Subir Sachdev[1,2] — [1]Department of Physics, Harvard University, Cambridge, USA — [2]Perimeter Institute for Theoretical Physics, Waterloo, Canada

Spatially isotropic critical quantum states in d spatial dimensions which have the hyperscaling property have an optical conductivity that scales as $\omega^{(d-2)/z}$ for high frequencies $\omega >> T$, where T is the temperature and z the dynamic critical exponent. We examine the Ising-nematic quantum critical point in $d = 2$ using the fixed point theory[1] and compute the optical conductivity in an expansion in $\epsilon = 5/2 - d$. We show that hyperscaling is violated at this quantum critical point and discuss the scaling behaviour of the optical conductivity at $T = 0$.

[1] Dalidovich and Lee, PRB **88**, 245106 (2013)

TT 35.6 Tue 15:15 H21

Dimensionless ratios: characteristics of quantum liquids and their phase transitions — Yi-Cong Yu[1], Yang-Yang Chen[1], Hai-Qing Lin[2], •Rudolf A. Römer[3], and Xi-Wen Guan[1,4,5] — [1]Wuhan Institute of Physics and Mathematics, Chinese Academy of Sciences, Wuhan 430071, China — [2]Beijing Computational Science Research Center, Beijing 100094, China — [3]University of Warwick, Coventry, CV4 7AL, UK — [4]Center for Cold Atom Physics, Chinese Academy of Sciences, Wuhan 430071, China — [5]Australian National University, Canberra ACT 0200, Australia

Dimensionless ratios of physical properties can be constant in low-temperatures phases in a wide variety of materials. As such, the Wilson ratio (WR), the Kadowaki-Woods ratio and the Wiedemann-Franz law capture essential features of Fermi liquids in metals, heavy fermions, etc. Here we prove that the phases of many-body interacting multi-component quantum liquids in one dimension can be described by WRs based on the compressibility, susceptibility and specific heat associated with each component. These WRs arise due to surprisingly simple additivity rules within subsystems reminiscent of the rules for multi-resistor networks in series and parallel. Using experimentally realized multi-species cold atomic gases as examples, we prove that the Wilson ratios uniquely identify phases of Tomonaga-Luttinger liquids, while providing universal scaling relations at the boundaries between phases. Their values within a phase identify the internal degrees of freedom of said phase such as its spin-degeneracy.

TT 35.7 Tue 15:30 H21

Many-body localization from one particle density matrix — •Soumya Bera[1], Henning Schomerus[2], Fabian Heidrich-Meisner[3], and Jens Bardarson[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden, Germany — [2]Lancaster University, Lancaster, United Kingdom — [3]Ludwig-Maximilians-Universitaet Munchen, Munich, Germany

We show that the one-particle density matrix ρ can be used to characterize the interaction-driven many-body localization transition in isolated fermionic systems. The natural orbitals (the eigenstates) are localized in the many-body localized phase and spread out when one enters the delocalized phase, while the occupation spectrum (the set of eigenvalues) reveals the distinctive Fock- space structure of the many-body eigenstates, exhibiting a step-like discontinuity in the localized phase. The associated one-particle occupation entropy is small in the localized phase and large in the delocalized phase, with diverging fluctuations at the transition.