O 44: Low-Dimensional Systems: 2D - Theory (TT jointly with O)

Time: Wednesday 9:30–13:00 Location: BEY 81

O 44.1 Wed 9:30 BEY 81

Critical theory of the spin quantum Hall transition — •Roberto Bondesan — Institute of theoretical physics, Köln, Deutschland

The spin quantum Hall (SQH) transition is a 2+1 dimensional Anderson transition between topological phases distinguished by different integer values of the spin conductance. In contrast to the celebrated integer quantum Hall transition, in the SQH case, critical exponents governing low moments of observables are known exactly. In this talk I will address the problem of characterizing completely the exponents of the theory beyond low moments. For this puropouse I will explain recent insights on the classification of scaling fields at Anderson transitions, which allow to perform efficient numerical studies and conjecture the multifractal spectrum of the theory.

O 44.2 Wed 9:45 BEY 81

Pure scaling operators at the integer quantum Hall plateau transition — Roberto Bondesan, •Daniel Wieczorek, and Martin Zirnbauer — Universität zu Köln, Institut für theoretische Physik, Zülpicher Straße 77, 50937 Köln

Despite considerable effort, the conformal field theory underlying the integer quantum Hall plateau transition is still not known. We circumvent the fact that conductances in the Chalker-Coddington model do not show pure scaling behaviour by introducing a new family of scattering observables corresponding to n-point functions of conformal primary fields at the plateau transition. Disorder averages of these observables correspond to lattice pure scaling operators in the supersymmetric vertex model. We also present numerical results for the multifractal spectra of 2 and 3 point functions.

O 44.3 Wed 10:00 BEY 81

Plasmons due to the interplay of Dirac and Schrödinger fermions — •Stefan Jürgens, Paolo Michetti, and Björn Trauzettel — Institute of Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany

We study the interplay between Dirac and Schrödinger fermions in the polarization properties of a two-dimensional electron gas (2DEG). Specifically, we analyze the low-energy sector of narrow-gap semiconductors described by a two-band Kane model. In the context of quantum spin Hall insulators, particularly, in Hg(Cd)Te quantum wells, this model is named Bernevig-Hughes-Zhang model. Interestingly, it describes electrons with intermediate properties between Dirac and Schrödinger fermions. We calculate the dynamical dielectric function of such a model at zero temperature within random phase approximation. Surprisingly, plasmon resonances are found in the intrinsic (undoped) limit, whereas they are absent – in that limit – in graphene as well as ordinary 2DEGs. Additionally, we demonstrate that the optical conductivity offers a quantitative way to identify the topological phase of Hg(Cd)Te quantum wells from a bulk measurement.

O 44.4 Wed 10:15 BEY 81

Correlated spinless fermions on the honeycomb lattice — •Martin Hohenadler[1] and Maria Daghofer[2] — [1]University of Würzburg, Germany — [2]IFW Dresden, Germany

We study the phase diagram of spinless fermions on the honeycomb lattice with nearest– (V_1) and next-nearest neighbour repulsion (V_2) using numerical methods. At the mean-field level, this model has been shown to describe an interaction-generated quantum anomalous Hall (QAH) phase with nonzero Chern index [Raghu *et al.*, PRL **100**, 156401 (2008)]. Our exact results reveal that this phase is completely suppressed by quantum fluctuations. However, for small V_2, we find that V_2 enhances bond order correlations that resemble the mean-field bond order in the QAH phase. This weak-coupling tendency toward a QAH state suggests that the phase may be realized in other models.

O 44.5 Wed 10:30 BEY 81

The π flux honeycomb lattice: a topological crystalline insulator. — •Martin Bercx, Martin Hohenadler, and Fakher F. Assaad — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, D-97074 Würzburg

We consider the Kane-Mele-Hubbard model with intrinsic spin-orbit coupling λ supplemented by a π flux threading each honeycomb plaquette. At $U = 0$ and in each spin sector the band structure is characterized by a Chern number $C = \pm 2$. Furthermore fine tuning of λ leads to a point of quadratic band crossing associated with a topological phase transition. Bulk quantum Monte Carlo simulations reveal a magnetically ordered phase which extends to weak couplings at the value of λ where the quadratic band crossing occurs. Although the spinful model carries two helical edge states and is explicitly shown to be a Z_2 trivial insulator, its edge states are robust due to protection by lattice translation symmetry. We present quantum Monte Carlo calculations which reveal that well defined edge states remain even in the case of strong interactions.

O 44.6 Wed 10:45 BEY 81

Density Functional Description of Two-Dimensional Fermi Gases — •Martin-Isbjörn Trappe[1], Hui Khoon Ng[1], Cord Axel Müller[2], and Berthold-Georg Englert[1] — [1]Centre for Quantum Technologies, National University of Singapore — [2]Department of Physics, University of Konstanz, Germany

Several methods suggest the gradient corrections beyond the Thomas-Fermi (TF) kinetic energy functional to vanish for two-dimensional systems at zero temperature. However, the TF functional does not coincide with the exact functional, implying the existence of corrections. We present a systematic derivation of such first order gradient corrections by means of the Wigner function and test the result employing the exactly known particle density of spin-1/2-fermions in a two-dimensional harmonic trap.

O 44.7 Wed 11:00 BEY 81

Renormalization group approach to non-analytic corrections in Fermi liquid theory — •Casper Drukier[1,2], Philipp Lange[1,2], and Peter Kopietz[1,2] — [1]Institut für Theoretische Physik, J.W.Goethe-Universität Frankfurt, Frankfurt am Main, Germany — [2]Department of Physics, University of Florida, Gainesville, Florida, USA

We calculate the leading non-analytic magnetic field dependence of the free energy and spin-susceptibility of a two-dimensional Fermi liquid using functional renormalization group methods, with bosonized particle-hole fluctuations. At weak coupling we recover the perturbative results of Maslov and Chubukov [PRB 79, 075112 (2009)]. We go beyond perturbation theory by including self-energy and vertex corrections within a truncated vertex expansion and present explicit results for the leading non-analytic correction to the spin-susceptibility and other Fermi liquid parameters as a function of interaction strength.

15 min. break.

O 44.8 Wed 11:30 BEY 81

From infinite to two dimensions through the functional renormalization group — Ciro Taranto[1], Sabine Andergassen[2], Johannes Bauer[3], Karsten Held[1], Andrey Katanin[4], Walter Metzner[5], Georg Rohringer[1], and •Alessandro Toschi[1] — [1]Institute for Solid State Physics, Vienna University of Technology 1040 Vienna, Austria — [2]Faculty of Physics, University of Vienna, 1090 Vienna, Austria — [3]Department of Physics, Harvard University, 17 Oxford St., MA 02138, USA — [4]Institute of Metal Physics, Russian Academy of Sciences and Ural Federal University, Ekaterinburg, Russia — [5]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany

We present a novel scheme[1] for an unbiased and non-perturbative treatment of strongly correlated fermions. The proposed approach combines two of the most successful many-body methods, i.e., the dynamical mean field theory (DMFT) and the functional renormalization group (fRG). Physically, this allows for a systematic inclusion of non-local correlations via the flow equations of the fRG, after the local correlations are taken into account non-perturbatively by the DMFT. To demonstrate the feasibility of the approach, we present numerical results for the two-dimensional Hubbard model at half-filling.

[1] C. Taranto, S. Andergassen, J. Bauer, K. Held, A. Katanin, W. Metzner, G. Rohringer, and A. Toschi, arXiv: 1307.3475.

O 44.9 Wed 11:45 BEY 81

Efficient 2D density matrix renormalization group in mixed

real- and momentum-space representation — •Johannes Motruk[1], Michael P. Zaletel[2], Roger S. K. Mong[3], and Frank Pollmann[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, 01187 Dresden, Germany — [2]Department of Physics, University of California, Berkeley, California 94720, USA — [3]Department of Physics, California Institute of Technology, Pasadena, California 91125, USA

Density matrix renormalization group (DMRG) is a powerful numerical technique for both 1D and 2D systems. The traditional implementation for a 2D system requires an ordering of sites to form an effective 1D chain for simulation. We present a variation of the DMRG technique that utilizes a real-space representation in one direction and momentum-space representation in the perpendicular direction of the lattice. We demonstrate how the mixed representation reduces the computational costs by using momentum as a conserved quantity—and as a by product—produces the momentum-resolved entanglement spectrum. As an application, we map out the phase diagram of a tight-binding model of spinless fermions with nearest-neighbour interactions on the square lattice. For this model, we give performance benchmarks comparing the mixed basis to the traditional real-space basis.

O 44.10 Wed 12:00 BEY 81

Dimensional-Crossover-Driven Mott Transition: A Variational Cluster Approach — •Benjamin Lenz and Thomas Pruschke — Institut für Theoretische Physik, Georg-August-Universität Göttingen, Germany

The dimensional-crossover-driven Mott transition has been studied recently for a frustrated Hubbard model with next-nearest neighbor hopping at finite temperatures [Raczkowski, Assaad, PRL 109 (2012)]. Here, we study this crossover from one to two dimensions at zero temperature by means of the variational cluster approximation (VCA) for fixed frustration as function of the interaction. The transition at zero temperature is found to be continuous, and results for various dynamic and static quantities are discussed as a function of cluster size.

O 44.11 Wed 12:15 BEY 81

Superconductivity in the two-dimensional t-t'-Hubbard model — •Andreas Eberlein and Walter Metzner — Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany

Using a recently developed renormalization group method for fermionic superfluids, we determine conditions for d-wave superconductivity in the ground state of the two-dimensional Hubbard model at moderate interaction strength, and we compute the pairing gap in the superconducting regime. A pairing instability signaled by a divergent flow in the Cooper channel leads to a superconducting state in all studied cases. The next-to-nearest neighbor hopping t' plays a crucial role in the competition between antiferromagnetism and superconductivity. A sizable t' is necessary to obtain a sizable pairing gap.

O 44.12 Wed 12:30 BEY 81

Unconventional superconductivity in the two dimensional Edwards model — •Dai-Ning Cho and Steffen Sykora — Institute for Theoretical Solid State Physics, IFW Dresden, D-01069 Dresden, Germany

The nature of charge transport within a correlated background medium can be described by spinless fermions coupled to bosons in the model introduced by Edwards. Employing the analytical projector-based renormalization method (PRM), we obtain a solvable effective Hamiltonian $\tilde{\mathcal{H}}$ which consists of a decoupled system of renormalized conduction electrons and a bosonic term with renormalized dispersion $\tilde{\omega}_{\mathbf{q}}$ which is generated naturally within the renormalization procedure. This method has been applied successfully to the 1D Edwards model where unbiased numerical results could be confirmed by the PRM. For the 2D model we show results for the effective one-particle dispersions of electrons and bosons in the whole Brillouin zone and for different values of the electron filling. In particular, we find strong dispersion of boson modes indicating a quantum phase transition to an unconventional superconducting state mediated by strong charge fluctuations. We show that the pairing changes its character from s- to d-wave symmetry.

O 44.13 Wed 12:45 BEY 81

Phase diagram of the square lattice bilayer Hubbard model: A Variational Monte Carlo study — Robert Rüger[1,2], •Luca Fausto Tocchio[1,3], Roser Valentí[1], and Claudius Gros[1] — [1]University of Frankfurt, Germany — [2]Scientific Computing & Modelling NV, Amsterdam, The Netherlands — [3]SISSA, Trieste, Italy

We investigate the phase diagram of the square lattice bilayer Hubbard model at half filling with the variational Monte Carlo method for both the magnetic and the paramagnetic case as a function of interlayer hopping $t_\perp$ and on-site Coulomb repulsion U. With this study we resolve some discrepancies in previous calculations based on the dynamical mean field theory, and we are able to determine the nature of the phase transitions between metal, Mott insulator and band insulator. In the magnetic case we find only two phases: An antiferromagnetic Mott insulator at small $t_\perp$ for any value of U and a band insulator at large $t_\perp$. At large U values we approach the Heisenberg limit. The paramagnetic phase diagram shows at small $t_\perp$ a metal to Mott insulator transition at moderate U values and a Mott to band insulator transition at larger U values. We also observe a reentrant Mott insulator to metal transition and metal to band insulator transition for increasing $t_\perp$ in the range of $5.5t < U < 7.5t$. Finally, we discuss the obtained phase diagrams in relation to previous studies based on different many-body approaches.