TT 24: Correlated Electrons: Low-dimensional Systems - Models

Time: Wednesday 14:00–19:00 Location: H 2053

TT 24.1 Wed 14:00 H 2053

Particle-hole symmetry and the Pfaffian state — •Bernd Rosenow, Michael Levin, and Bertrand I. Halperin — Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA

The Moore-Read Pfaffian (Pf) state is believed to be a strong candidate for the observed quantum Hall plateau at filling fraction $\nu = 5/2$. This possibility is particularly exciting since the quasiparticle excitations in this state carry non-abelian statistics. Much work has been devoted to understanding the basic physical properties of the Pf state. However, one aspect of the Pf state has not been addressed - namely, its behavior under particle-hole (PH) conjugation of electrons in the spin-aligned partially occupied second Landau level. This issue is important because, to a good approximation, the Hamiltonian of the $\nu = 5/2$ FQH system is symmetric under this PH conjugation.

We show that the particle-hole conjugate of the Pfaffian state - or "anti-Pfaffian" state - is in a different universality class from the Pfaffian state, with different topological order. The two states can be distinguished by both their bulk and edge physics though the difference is most dramatic at the edge: the edge of the anti-Pfaffian state has a composite structure that leads to a different thermal Hall conductance and different tunneling exponents than the Pfaffian state. At the same time, the two states are exactly degenerate in energy for a $\nu = 5/2$ quantum Hall system in the idealized limit of zero Landau level mixing. Thus, both are good candidates for the observed $\sigma_{xy} = \frac{5}{2}(e^2/h)$ quantum Hall plateau.

TT 24.2 Wed 14:15 H 2053

Emergent fermions and anyons in the Kitaev model — •Kai P. Schmidt[1], Sebastien Dusuel[2], and Julien Vidal[3] — [1]Institute of Theoretical Physics, Ecole Polytechnique Federal de Lausanne, CH-1015 Lausanne, Switzerland — [2]Lycee Louis Thuillier, 70 Boulevard de Saint Quentin, 80098 Amiens Cedex 3, France — [3]Laboratoire de Physique Theorique de la Matiere Condensee, CNRS UMR 7600,

We study the gapped phase of the Kitaev model on the honeycomb lattice using perturbative continuous unitary transformations. The effective low-energy Hamiltonian is found to be an extended toric code with interacting anyons. High-energy excitations are emerging free fermions which are composed of hardcore bosons with an attached string of spin operators. The excitation spectrum is mapped onto that of a single particle hopping on a square lattice in a magnetic field. The present approach yields analytical perturbative results in the thermodynamical limit and gives a simple description of the spectrum without using the Majorana or the Jordan-Wigner fermionization initially proposed to solve this problem.

TT 24.3 Wed 14:30 H 2053

Novel many-body states on the honeycomb lattice — •Carsten Honerkamp — Theoretische Physik, Universität Würzburg

We apply a functional renormalization group scheme to search for interesting many-body states of electrons on the honeycomb lattice, interacting by onsite and up to second nearest-neighbor terms. Near half band-filling, critical minimal interaction strengths are required for instabilities toward antiferromagnetic or charge-density wave order. A strong second-nearest neighbor repulsion drives the system into a quantum-spin-Hall insulating state. Away from half filling, f-wave triplet pairing and $d+id$ singlet pairing instabilities are found to emerge out of density-wave regimes.

TT 24.4 Wed 14:45 H 2053

Dynamic structure factor of Luttinger liquids — •Peyman Pirooznia[1], Florian Schütz[2], and Peter Kopietz[1] — [1]Institut für Theoretische Physik, Universität Frankfurt, Max-von-Laue-Strasse 1, 60438 Frankfurt, Germany — [2]Department of Physics, Brown University, Providence, RI 02912, USA

We calculate the dynamic structure factor $S(\omega, q)$ of non-relativistic fermions with quadratic energy dispersion and long-range density-density interaction, assuming that the Fourier transform f_q is the interaction is dominated by momentum transfers $q \lesssim q_c \ll k_F$, where k_F is the Fermi momentum. Using functional bosonization and the known properties of symmetrized closed fermion loops, we obtain an expansion of the inverse irreducible polarization $\Pi_*^{-1}(q, \omega)$ to second order in the small parameter q_c/k_F. In contrast to conventional bosonization and to direct fermionic perturbation theory, in our approach we do not generate unphysical mass-shell singularities. We then show that for $q \ll q_c$ the width w_q of the single-pair particle-hole continuum on the frequency axis scales as q^2/m. However, for $q \to 0$ most of the spectral weight is carried by the collective zero sound (ZS) mode, whose damping γ_q is parametrically smaller than w_q. For sharp cutoff in momentum space, $f_q = f_0\Theta(q_c - q)$, we find to order $(q_c/k_F)^2$ that the ZS mode is not damped at all. For smooth cutoff the ZS damping scales as q^n with $n \geq 3$ for $q \to 0$, where the value of n depends on the functional form of f_q. We also comment on previous attempts to calculate the damping γ_q of the ZS peak in Luttinger liquids.

TT 24.5 Wed 15:00 H 2053

Towards Experimental Verification of Luttinger Liquid Behavior — •Peter Wächter[1], Volker Meden[2], and Kurt Schönhammer[1] — [1]Institut für Theoretische Physik, Universität Göttingen, Germany — [2]Institut für Theoretische Physik, RWTH Aachen, Germany

Luttinger Liquid (LL) behavior of metallic one-dimensional (1d) electron systems is well established as a theoretical concept. It manifests itself e.g. in the power law scaling of a variety of physical observables as functions of external parameters with exponents depending on a single parameter, the LL parameter K. However, experiments revealing clear indications of LL behavior are very rare. One major difficulty is to convincingly exclude any other source than LL physics for the observed scaling. To cope with this problem we propose a scheme to extract K from two different observables as functions of two different external parameters p_1 and p_2. Consistency of the findings in an experiment, that means $K(p_1) \approx K(p_2)$, would provide strong evidence for LL physics.

TT 24.6 Wed 15:15 H 2053

Effects of dissipation on disordered Luttinger liquids — •Zoran Ristivojevic and Thomas Nattermann — Institut für Theoretische Physik, Universität zu Köln, Zülpicher Straße 77, 50937 Köln, Germany

We study theoretically the low energy properties of 1D Luttinger liquids in the presence of dissipation and disorder. Both the case of a single impurity (Kane-Fisher) and that of gaussian randomness (Giamarchi-Schulz) are considered in a renormalization group approach. We show that dissipation drastically changes the phase diagram and the conductance/conductivity in both cases. The approach is an extension of recent work of Cazallila et al. (Phys. Rev. Lett. 97, 076401 (2006)).

15 min. break

TT 24.7 Wed 15:45 H 2053

Density Distribution in Finite One-Dimensional Interacting Fermion Systems — •Stefan Soeffing and Sebastian Eggert — FB Physik, TU Kaiserslautern, 67663 Kaiserslautern

We numerically investigate the ground state density distribution of the Hubbard model with open boundary conditions by means of the Density Matrix Renormalization Group (DMRG). In addition to the expected Friedel oscillations with wave vector $2k_F$, we also observe $4k_F$ Wigner crystal oscillations which are in certain cases the dominant contribution.

We systematically analyze the amplitude of the density oscillations as a function of system length, lattice filling and interaction strength. The decay of the standing waves with respect to the distance from the boundaries is compared with the predicted power laws from Luttinger Liquid theory.

TT 24.8 Wed 16:00 H 2053

Local Density of States of a Finite Quantum Wire: Numerical Results from DMRG in Comparison with Bosonization Results — Imke Schneider and •Sebastian Eggert — FB Physik, TU Kaiserslautern, 67663 Kaiserslautern

We consider a finite quantum wire, modeled by a one-dimensional system of locally interacting Fermions. We are able to numerically obtain the local density of states (LDOS) with the help of the density matrix

renormalization group (DMRG). We believe this is the first time that the LDOS was calculated energy and spatially resolved for an interacting lattice model. We are able to compare to analytic expressions for individual energy levels in systems with open boundary conditions from Luttinger Liquid theory.

In this way, a detailed understanding of the LDOS for each individual energy level can be obtained in both fermionic and bosonic pictures. Certain degeneracies of the Luttinger Liquid spectrum are lifted in the lattice model by band curvature and interaction effects, leading to a large number of states and energy levels in the LDOS.

TT 24.9 Wed 16:15 H 2053

The magnetic polaron in the one-dimensional Kondo lattice model away from half filling — •Sebastian Smerat[1,2], Ian P. McCulloch[3], Ulrich Schollwöck[2], and Herbert Schoeller[1] — [1]Institut für Theoretische Physik A, RWTH Aachen, D-52056 Aachen, Deutschland — [2]Institut für Theoretische Physik C, RWTH Aachen, D-52056 Aachen, Deutschland — [3]School of Physical Sciences, the University of Queensland, QLD 4072, Australia

Recent progress in the fabrication of nanosized materials may in the near future allow to load nanotubes with, e.g., fullerenes. We expect the magnetic and transport properties of such materials to be adequately described by a one-dimensional Kondo lattice model. This motivates our numerical analysis of the model. Our main focus is on the properties of magnetic polarons, which previously have been argued to exist in both the limit of a half-filled and an empty conduction band. Using a state-of-the-art numerical method, the density matrix renormalization group algorithm, we compute the spectral functions of the model as a function of filling. As a main result, we provide clear evidence for the existence of the magnetic polaron away from half filling. A careful analysis of the spectral functions allows us to determine lower bounds for the quasi-particle life-time.

TT 24.10 Wed 16:30 H 2053

Hybrid approach for quantum antiferromagnets in a uniform magnetic field: Method — •Andreas Kreisel, Francesca Sauli, Nils Hasselmann, and Peter Kopietz — Institut für Theoretische Physik, Universität Frankfurt, Max-von-Laue Straße 1, 60438 Frankfurt, Germany

The properties of ordered quantum antiferromagnets can be calculated by an expansion in inverse powers of the spin quantum number S via the Holstein-Primakoff transformation of the underlying Heisenberg model, or by a renormalization group approach to the non-linear sigma model (NLSM). The relation between these descriptions can be made precise by expressing the canonical magnon operators in the spin-wave approach in terms of hermitian field operators which represent the uniform and staggered components of the spin operators. An effective action for the staggered spin fluctuations (low energy degrees of freedom) has been derived for the case of vanishing magnetic field [1]. We now generalize the approach to quantum antiferromagnets in a uniform magnetic field and discuss the resulting interaction vertices in comparison with those of the NLSM and the conventional $1/S$ expansion.
[1] N. Hasselmann and P. Kopietz, Europhys. Lett. **74**, 1067 (2006)

TT 24.11 Wed 16:45 H 2053

Hybrid approach for quantum antiferromagnets in a uniform magnetic field: Application — •Francesca Sauli, Andreas Kreisel, Nils Hasselmann, and Peter Kopietz — Institut für Theoretische Physik, Universität Frankfurt, Max-von-Laue Strasse 1, 60438 Frankfurt, Germany

We use a hermitian parameterization of the canonical magnon operators obtained from the usual Holstein-Primakoff transformation and combine it with a $1/S$-expansion of the Heisenberg model to acquire the effective action for quantum antiferromagnets (QAF). Integrating over the fields associated with the uniform spin fluctuations yields a field theory for the staggered spin fluctuations on a lattice but avoids the cutoff ambiguities of the non-linear sigma model (NLSM). Using this effective lattice action for the staggered spin-fluctuations of a QAF subject to a uniform magnetic field we explicitly calculate the leading $1/S$-corrections to the spin wave velocity as well as the damping of the staggered spin fluctuations.

TT 24.12 Wed 17:00 H 2053

Two particle excitations of projected wavefunctions. — •Tejaswini Dalvi and Claudius Gros — ITP, J.W. Goethe University, Frankfurt

The study of projected wavefunctions involves extensive use of Gutzwiller approximation (GA), along with Variational Monte Carlo (VMC), to study ground state properties. Recent studies include, study of properties of elementary excitations in doped Mott-Hubbard systems in detail by Renormalized Mean Field Theory (RMFT) and VMC. Important progress has been made in extending the technique of GA to calculate matrix elements in partially projected wavefunctions.

This generalization has allowed construction of normalized projected excitations for Fermi sea and BCS wavefunctions and evaluation of matrix elements between ground state and excited states. We here propose to study the particle-particle, hole-hole and particle-hole scattering for projected particle and projected hole state by generalised GA and VMC. This aims at laying foundation for a "Projected Fermi-liquid Theory".

15 min. break

TT 24.13 Wed 17:30 H 2053

Doped ladders under magnetic field — •Guillaume Roux[1], Edmond Orignac[2], Steven R. White[3], and Didier Poilblanc[4] — [1]Institut für theoretische Physik C, RWTH Aachen, Aachen, Germany — [2]Laboratoire de Physique de l'École Normale Supérieure de Lyon, ENS-Lyon, CNRS UMR5672, Lyon, France — [3]Department of Physics and Astronomy, University of California, Irvine, USA — [4]Laboratoire de Physique Théorique, IRSAMC, Université Paul Sabatier, CNRS UMR5152, Toulouse, France

We study the effect of the magnetic field on doped two-leg ladders by means of density-matrix renormalization group (DMRG) and bosonization techniques. It is shown that the Zeeman effect induces a magnetization plateau controlled by hole doping and a FFLO phase. This latest is associated with an exceeding of Pauli limit which can help with the interpretation of experiments. Furthermore, superconducting non-polarized triplet fluctuations are also found to emerge at high magnetic field. In addition, the orbital effect is included and the transverse current correlations are shown to be commensurate with the charge density ones as soon as the magnetic field is turn on. Lastly, the diamagnetic susceptibility probes the commensurate phases appearing for commensurate dopings.

TT 24.14 Wed 17:45 H 2053

Effect of shell structure on Anderson orthogonality catastrophe — •Swarnali Bandopadhyay and Martina Hentschel — Max Planck Institute for the Physics of Complex Systems, N{\"o}thnitzer Str. 38, 01187 Dresden, Germany

We study the Anderson orthogonality catastrophe (AOC) for parabolic quantum dots (PQD). AOC is one of the many-body responses leading to Fermi-edge singularities in, e.g., the photo-absorption cross-section of metals. We use rank-one perturbation to model the static impurity created by an x-ray exciting a core electron into the conduction band. A PQD is characterized by an inherent shell structure. The degeneracy in a shell is slightly lifted in presence of a weak magnetic field. The behavior of a PQD is governed by two energy-scales: The inter-shell spacing (set by the oscillator's bare frequency) and the intra-shell level spacing (set by the magnetic field). We study the statistics of the Anderson overlap for an uniform as well as a realistic mesoscopic PQD as a function of perturbation strength, position of the localized impurity, number of electrons and system size. The clustering of levels gives rise to an oscillatory behavior in Anderson overlap as a function of filling of the PQD levels. In particular, we find a pronounced AOC, related to the quasi-degeneracy of levels, whenever a new shell is opened up. This inherent shell structure survives in the presence of mesoscopic fluctuations, when we observe the Anderson overlap to remain unchanged despite adding several electrons to the system. A similar bunching phenomenon has been observed in transport measurements on quantum dots by Zhitenev et. al.[PRL,79, 2308 (1997)].

TT 24.15 Wed 18:00 H 2053

Konkurrenz von Coulomb-Abstoßung und Elektron-Phonon-Wechselwirkung in einem eindimensionalen Elektron-Phonon-System — •Gerd Zschaler, Steffen Sykora und Klaus W. Becker — Institut für Theoretische Physik, TU Dresden, Germany

Wir untersuchen ein verallgemeinertes Su-Schrieffer-Heeger Modell mit zusätzlicher Coulomb-Abstoßung zwischen nächsten Nachbarn. Während die Elektron-Phonon-Wechselwirkung eine Dimerisierung auf den Bonds favorisiert, führt die Coulomb-Abstoßung zu einer Ladungs-

dichtewelle (CDW). Mit Hilfe der projektiven Renormierungsmethode (PRM) werden beide Wechselwirkungen sukzessive eliminiert, so dass ein renormiertes, entkoppeltes Elektron-Phonon-System resultiert. Der Einfluss der konkurrierenden Wechselwirkungen auf die renormierten Einteilchenenergien wird untersucht.

TT 24.16 Wed 18:15 H 2053

Entanglement percolation at quantum phase transitions in random quantum magnets — •Yu-Cheng Lin[1], Ferenc Igloi[2,3], and Heiko Rieger[1] — [1]Theoretische Physik, Universität des Saarlandes, 66041 Saarbrücken, Germany — [2]Research Institute for Solid State Physics and Optics, H-1525 Budapest, Hungary — [3]Institute of Theoretical Physics, Szeged University, H-6720 Szeged, Hungary

We study the scaling of the entropy quantifying the degree of quantum entanglement between two regions in a bipartite random quantum Ising model in two dimensions, using an asymptotically exact renormalization group treatment [1]. This system undergoes a quantum phase transition at a certain transverse field strength, at which point the von Neumann entanglement entropy of a subsystem violates the "area law", providing evidence for non-trivial and long-range quantum entanglement in the ground state. The entanglement entropy per surface area of a subsystem diverges in a double logarithmic form, arising from a type of percolation of the critical ground state that is fundamentally different from classical percolation. The latter can be found in an analogous quantum system with random bond dilution; here the area law is valid at the quantum critical point, which implies that entanglement cannot be regarded as an indicator of quantum criticality for higher dimensional systems in the way as for one-dimensional cases.

[1] Y.-C. Lin, F. Iglói and H. Rieger, Phys. Rev. Lett. 99, 147202 (2007).

TT 24.17 Wed 18:30 H 2053

Spin-orbit coupling and electron correlations in quantum wires — •Jens Eiko Birkholz[1] and Volker Meden[2] — [1]Institut für Theoretische Physik, Universität Göttingen, D- 37077 Göttingen, Germany — [2]Institut für Theoretische Physik A, RWTH Aachen, D-52056 Aachen, Germany

We investigate the influence of the spin-orbit coupling on the transport properties of mesoscopic quantum wires. For a continuum model we discuss the effect of the spin-orbit interaction resulting from the lateral potential necessary to confine the two-dimensional electron gas, ocurring at a semiconductor hetero junction, to a quasi one-dimensional wire geometry. The spin polarization at a potential step in the presence of a magnetic field is analyzed. We introduce a lattice model which shows similar low-energy physics. For this lattice model we use the functional renormalization group method to investigate the role of the two-particle interaction (Coulomb interaction). The interplay of spin-orbit coupling, potential barriers, and electron correlations leads to interesting phenomena in the low-energy physics regime.

TT 24.18 Wed 18:45 H 2053

Single hole and vortex excitations in the doped Rokhsar-Kivelson quantum dimer model on the triangular lattice — •Hugo Ribeiro[1,2], Samuel Bieri[2], and Dmitri Ivanov[2] — [1]Institute of theoretical physics C, RWTH Aachen, Germany — [2]Institute of theoretical physics, EPF Lausanne, Switzerland

We consider the doped Rokhsar-Kivelson quantum dimer model on the triangular lattice with one mobile hole (monomer) at the RK point. The motion of the hole is described by two branches of excitations: the hole may either move with or without a trapped Z2 vortex (vison). We perform a study of the hole dispersion in the limit where the hole hopping amplitude is much smaller than the inter-dimer interaction. In this limit, the hole without vison moves freely and has a tight-binding spectrum. On the other hand, the hole with a trapped vison is strongly constrained due to interference effects and can only move via higher-order virtual processes.