TT 36: Correlated Electrons: 1D Theory

Time: Tuesday 9:30–12:15 Location: HFT-FT 101

TT 36.1 Tue 9:30 HFT-FT 101

Dynamical measurement of the interaction strength in helical Luttinger Liquids — •Tobias Müller[1], Ronny Thomale[1], Björn Trauzettel[1], Erwann Bocquillon[2], and Oleksiy Kashuba[1] — [1]Institute for Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg — [2]Laboratoire Pierre Aigrain, Ecole Normale Supérieure-PSL Research University, CNRS, Université Pierre et Marie Curie-Sorbonne Universités, Université Paris Diderot-Sorbonne Paris Cité, 75231 Paris Cedex 05

Based on an equations of motion description of helical Luttinger Liquids we propose a setup to measure the interactions inside a one-dimensional wire directly. Using a capacitively coupled gate rather than purely ohmic contacts we can extract the Luttinger parameter both directly and in the low frequency expansion of a frequency-resolved conductivity measurement. We also discuss the influence of the precise form of the change in interactions at ohmic contacts within the setup.

TT 36.2 Tue 9:45 HFT-FT 101

Superconducting proximity effect in a helical Luttinger liquid coupled to single-electron sources — •Flavio Ronetti[1,2], Matteo Carrega[3], Jérôme Rech[2], Thibaut Jonckheere[2], Thierry Martin[2], and Maura Sassetti[1] — [1]Università di Genova and CNR-SPIN, Via Dodecaneso 33, 16146, Genova, Italy. — [2]Aix Marseille Univ, Université de Toulon, CNRS, CPT, Marseille, France. — [3]NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Piazza San Silvestro 12, I-56127 Pisa, Italy.

The superconducting proximity effect in a helical Luttinger liquid induces correlations between left-movers and right-movers channels and, in the presence of the Rashba spin-orbit coupling, also between particles in the same channel [1]. We focus on the injection of single-electrons through a periodic train of Lorentzian pulses [2] along a helical Luttinger liquid coupled to a superconductor. We analyze the current-noise in this setup when a single channel or both channels are coupled to a single-electron source [3]. The presence of electron-electron interactions and Rashba coupling is considered and we suggest some possible experimental signatures of their strength.

[1] P. Virtanen, P. Recher, Phys. Rev B 85, 035310 (2012)
[2] J. Dubois et al., Nature (London) 502, 659 (2013).
[3] F. Ronetti et al., in preparation (2017).

TT 36.3 Tue 10:00 HFT-FT 101

Coherence and decoherence in beamsplitters for interacting edge state electrons — Andreas Schulz, •Imke Schneider, Sebastian Eggert, and James Anglin — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern

Recent studies have shown that simple intersections between one-dimensional channels can act as coherent beam splitters for non-interacting electrons. Here we examine how coherent splitting at such quantum wire crossings is affected by inter-particle interactions. We use the one-loop renormalization group to derive the effective impurity which represents the intersection within Luttinger liquid theory at low energy. For the special case of Luttinger $K = 1/2$, we compute exact time-dependent expectation values of charge density as well as density-density correlation functions. We find that when multiple charge density wave packets encounter the impurity from different directions, reflection and splitting of the packets depends on their relative phases, raising the prospect of Luttinger interferometry.

TT 36.4 Tue 10:15 HFT-FT 101

Tuning the Drude Weight of Dirac-Weyl Fermions in One-Dimensional Ring Traps — Manon Bischoff[1], Johannes Jünemann[1,2], Marco Polini[3], and •Matteo Rizzi[1] — [1]Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany — [2]Graduate School Materials Science in Mainz, Mainz, Germany — [3]Istituto Italiano di Tecnologia, Graphene Labs, Genova, Italy

We study the response to an applied flux of an interacting system of Dirac-Weyl fermions confined in a one-dimensional (1D) ring. Combining analytical calculations with density-matrix renormalization group results, we show that tuning of interactions leads to a unique many-body system that displays either a suppression or an enhancement of the Drude weight – the zero-frequency peak in the ac conductivity – with respect to the non-interacting value. An asymmetry in the interaction strength between same- and different-pseudospin Dirac-Weyl fermions leads to Drude weight enhancement. Viceversa, symmetric interactions lead to Drude weight suppression. Our predictions can be tested in mixtures of ultracold fermions in 1D ring traps.

[1] Bischoff *et al.*, arXiv:1706.02679

TT 36.5 Tue 10:30 HFT-FT 101

The resonant state at filling factor 1/2 in chiral fermionic ladders — •Andreas Haller[1], Matteo Rizzi[1], and Michele Burrello[2] — [1]Institute of Physics, Johannes Gutenberg University, 55099 Mainz, Germany — [2]Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark

Helical liquids have been experimentally detected in both nanowires and ultracold atomic chains as the result of strong spin-orbit interactions. In both cases the inner degrees of freedom can be considered as an additional space dimension, providing an interpretation of these systems as synthetic ladders, with artificial magnetic fluxes determined by the spin-orbit terms. In this work, we analyze such a quasi-one-dimensional ladder geometry and characterize the helical state which appears at filling factor 1/2. This state is generated by a gap arising in the spin sector of the corresponding Luttinger liquid and can be interpreted as the one-dimensional (1D) limit of a fractional quantum Hall state of bosonic pairs of fermions. We study its main features, focusing on entanglement properties and correlation functions and support our analytic results with matrix product state simulations.

TT 36.6 Tue 10:45 HFT-FT 101

Observation of a hierarchy of modes in an interacting 1D system — •Christopher J B Ford[1], Yiqing Jin[1], Maria Moreno[1], Wooi Kiat Tan[1], Anne Anthore[2], Jon P Griffiths[1], Ian Farrer[1], Geraint A C Jones[1], David A Ritchie[1], Oleksandr Tsyplyatyev[3], and Andrew Scholfield[4] — [1]University of Cambridge, UK — [2]Paris Diderot University, France — [3]University of Frankfurt, Germany — [4]University of Birmingham, UK

At low excitation energies, a system of interacting one-dimensional (1D) electrons can be described theoretically as a Tomonaga-Luttinger liquid. However, it is only in the last few years that theoreticians have developed models of the behaviour at energies comparable to the Fermi energy, predicting 'replicas' of the dispersion relation offset by multiples of the Fermi wave-vector. We measure momentum-resolved tunnelling of electrons between 1D wires formed within a GaAs heterostructure and a 2D electron gas used as a spectrometer and have previously found well-resolved spin-charge separation at low energy with appreciable interaction strength. Now we have detected structure resembling replicas, which dies away quite rapidly at high momentum, in line with the most recent theory.[1] We have fabricated arrays of wires with lengths between 1 and 20μm, after developing a reliable technique to make thousands of 'air-bridges' on each device. The replicas seem strongest in the short wires,[2] again as predicted by the theory.

[1] Tsyplyatyev *et al.*, Phys. Rev. Lett., **114**, 196401 (2015)
[2] Moreno *et al.*, Nat. Commun. **7**, 12784 (2016)

15 min. break.

TT 36.7 Tue 11:15 HFT-FT 101

Systematic reduction of Thermodynamic Bethe Ansatz equations by means of Bäcklund hierarchies — •Eyzo Stouten and Andreas Klümper — Bergische Universität Wuppertal, 42097 Wuppertal, Germany

For integrable systems there is an established way to calculate thermodynamics through the Thermodynamic Bethe Ansatz. The conventional method necessarily involves the characterization of the full spectrum of the Hamiltonian via combinatorial means. An alternative approach is to study the leading eigenvalue of a column to column or quantum transfer matrix (QTM), which is related to an infinite family of QTM by factorization of the bilinear fusion relations (of Hirota type). By studying the analyticity of the constituents of the QTM one can rewrite the fusion relations into non-linear integral equations (NLIE) that characterize the leading eigenvalue. This transformation only depends on some knowledge of the partial spectrum of the QTM.

To extract the thermodynamic properties at finite temperatures the infinite hierarchy of NLIE is truncated to a finite set at the cost of introducing a finite set of auxiliary equations. In previous works these auxiliary equations could only be derived in a heuristic manner for low rank systems. The goal of this research is to derive them in a systematic way by factorization of a set of bilinear Bäcklund equations and extending to arbitrary rank. The use of Bäcklund relations is inspired by a series of papers [1] where they where introduced because of their relation to the Hirota equations and the related fusion relations.

[1] Zabrodin et al., Nucl. Phys. B 790 (2008) 345

TT 36.8 Tue 11:30 HFT-FT 101

DC-Conductance of one-dimensional correlated systems derived by DMRG — •Jan-Moritz Bischoff and Eric Jeckelmann — Leibniz Universität Hannover, Hannover, Deutschland

We present an efficient method [1] for computing the zero-temperature linear conductance of correlated one-dimensional systems using the density-matrix renormalization group (DMRG). Like in [2], the model expresses the conductance as limits of dynamical correlation functions in finite systems within Linear Response Theory. These correlation functions can be calculated by dynamical DMRG. We tested the method first on non-interacting models for comparison with exact results and in order to determine an appropriate scaling of frequency, system size and spectral broadening. In addition, we extended the procedure to interacting systems using the one-dimensional spinless fermion model. The results were in good agreement with field-theoretical predictions (combined with the Bethe Ansatz solution) for the renormalization of conductance in a pure Luttinger liquid, as well as for the effects of an impurity in a Luttinger liquid [3]. We were also able to simulate the experimental more relevant setup of a wire that is coupled to leads and will present our first results.

[1] J.-M. Bischoff, E. Jeckelmann, PRB 96, 195111 (2017)
[2] D. Bohr, P. Schmitteckert, P.W. Wölfle, Europhys. Lett., 73, 246 (2006)
[3] C.L. Kane, M.P.A. Fisher, PRB 46, 15233 (1992)

TT 36.9 Tue 11:45 HFT-FT 101

Effective narrow ladder model for a spinless fermion wire on a semiconducting substrate — •Anas Abdelwahab and Eric Jeckelmann — Institut für Theoretische Physik, Leibniz Universität Hannover, Hannover, Germany

A spinless fermion wire coupled to a 3D-tight-binding substrate is approximated by a few-leg narrow ladder model (NLM) using the exact mapping introduced in Refs.[1] and [2]. Three phases are distinguished, namely, a one-component Luttinger liquid, a charge-density-wave (CDW) and a doped band insulator. We investigated the convergence of the single-particle excitation gap with increasing number of legs in the NLM. We confirm that the NLM is a good approximation to the 3D wire-substrate model in the one-component Luttinger liquid and the CDW phases. The NLM describes only qualitatively the doped band-insulator phase. The quantum phase transitions between the three phases are investigated as function of the wire-substrate coupling. The critical nearest-neighbor interactions increase with increasing the wire-substrate coupling.

Support from the DFG through the Research Units FOR 1700 is gratefully acknowledged.

[1] A. Abdelwahab, E. Jeckelmann, and M. Hohenadler, Phys. Rev. B 96, 035445 (2017).
[2] A. Abdelwahab, E. Jeckelmann, and M. Hohenadler, Phys. Rev. B 96, 035446 (2017).

TT 36.10 Tue 12:00 HFT-FT 101

Spectral flow for an integrable staggered superspin chain — •Konstantin Hobuss and Holger Frahm — Institut für Theoretische Physik, Leibniz Universität Hannover

The flow of the low energy eigenstates of a $U_q[sl(2|1)]$ superspin chain with alternating fundamental (3) and dual ($\bar{3}$) representations is studied as function of a twist angle determining the boundary conditions. The finite size spectrum is characterized in terms of scaling dimensions and quasi momenta representing the two families of commuting transfer matrices for the model which are even and odd under the interchange $3 \leftrightarrow \bar{3}$, respectively. Based on the extrapolation of our finite size data we find that under a variation of the boundary conditions from antiperiodic to periodic for the fermionic degrees of freedom levels from the continuous part of the spectrum flow into discrete levels and vice versa. The implications of our results on the underlying conformal field theory which describes the continuum limit are discussed.