TT 45: Correlated Electrons: 1D Theory

Time: Thursday 9:30–12:15 Location: HSZ 103

TT 45.1 Thu 9:30 HSZ 103

On the alternating spin chain with continuous spectrum of scaling dimensions — Mouhcine Azhari and •Andreas Klümper — Universität Wuppertal

We investigate the low-lying spectrum of an integrable staggered Heisenberg spin-1/2 chain possessing in the large length (L) limit a CFT structure with logarithmic corrections ($1/(\log L)^2$). This realizes a continuous spectrum of conformal weights similar to that of for instance the $SL(2,R)/U(1)$ black hole sigma model.

The quantum spin chain is exactly "solvable" by Bethe ansatz and other techniques from the theory of integrability. However, the analysis of the resulting Bethe Ansatz equations is challenging and manageable by numerical techniques only for relatively small sizes L. Integral equations for the distribution functions of the Bethe roots suffer from singularities of the kernel functions.

Due these phenomena and challenges the model attracted interest by several groups of authors (Ikhlef, Jacobsen, Saleur 08, 12; Frahm, Martins 12; Candu, Ikhlef 13; Frahm, Seel 14; Bazhanov, Kotousov, Koval, Lukyanov 20).

In our contribution we report on recent progress allowing us to rewrite already existing non-linear integral equations (NLIE) with a singular, i.e. long-ranged kernel in a novel form without such problems. We present results for the lowest lying excitations for system sizes $L = 10, 10^2, 10^3, ..., 10^9, ...$

TT 45.2 Thu 9:45 HSZ 103

Electron spin resonance as a direct probe of spinon interactions in a $S = 1/2$ chain — •Kirill Povarov[1,2], Timofei Soldatov[3], Ren-Bo Wang[4], Andrey Zheludev[1], Alexander Smirnov[3], and Oleg Starykh[4] — [1]Laboratory for Solid State Physics, ETH Zürich — [2]Dresden High Magnetic Field Laboratory (HLD), Helmholtz-Zentrum Dresden-Rossendorf (HZDR) — [3]P.L. Kaptiza Institute for Physical Problems RAS — [4]Department of Physics and Astronomy, University of Utah

The presence of well-hidden backscattering between the fractionalized spinon excitations was known to be a somewhat exotic part of the $S = 1/2$ chain physics. However, its dramatic consequences for the dynamics were realized recently [1]. They are challenging for observation, as applied field and nonzero momenta are simultaneously required. We have succeeded in the experimental verification of these effects using electron spin resonance as probe [2]. Our observations are enabled by the specific pattern of Dzyaloshinskii–Moriya interactions in our target material $K_2CuSO_4Br_2$. Description of the observed spectrum requires accounting for the backscattering on a qualitative level. Quantitative analysis allows us to estimate the backscattering constant as $2.4J$ (intrachain exchange), in agreement with the renormalization group predictions. This work has been supported by SNSF Division II (ETHZ), the NSF CMMT grant DMR-1928919 (U. Utah), and the RSF Grant 17-12-01505 (IPP).

[1] A. Keselman *et al.*, PRL **125**, 187201 (2020)
[2] K. Povarov *et al.*, PRL **128**, 187202 (2022) *Editor's Suggestion*

TT 45.3 Thu 10:00 HSZ 103

Dominant superconducting correlations in a Luttinger liquid induced by spin fluctuations — •Niels Henrik Aase and Asle Sudbø — Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

In the last decades, heterostructures of magnetic materials and various conductors have received much attention. Several studies have focused on the emergent interfacial phenomena and their possible application in spintronic devices. Motivated by this, we study the simplest equivalent heterostructure in one dimension: an interacting metallic chain coupled to a spin chain. Confining interacting electrons to one dimension causes the breakdown of Fermi liquid theory, so our study provides insight into how spin fluctuations can induce superconductivity in a strongly correlated non-Fermi liquid with repulsive electronic interactions only.

Treating the system using bosonization, we calculate the correlation functions of the electrons in the metal. Based on the non-universal power-law decay of different order parameters, we outline the electron phase diagram as a function of the interchain coupling and the interactions in the metal. The coupling favors triplet pairing, suggesting that the metal chain can sustain a spin-polarized supercurrent. In some parameter regimes, the superconducting triplet correlations persist in the case of repulsive interactions in the metal. The spin chain is thus an essential ingredient for overcoming electron repulsion in a Luttinger liquid.

TT 45.4 Thu 10:15 HSZ 103

The role of electron-electron interactions in electron emission from arrays of nanotubes — •Naira Grigoryan[1] and Piotr Chudzinski[1,2] — [1]Institute of Fundamental Technological Research, Polish Academy of Sciences, Adolfa Pawinskiego 5b, 02-106 Warsaw, Poland — [2]School of Mathematics and Physics, Queen's University Belfast, University Road, Belfast, NI BT7 1NN, United Kingdom

Nanotubes and nanorods have been recently established as very good materials to build electron sources in the cold emission process. These are 1D materials where electron-electron interactions are known to play a crucial role in their physics. The interactions in 1D systems lead to a collective modes' physics that is usually described using Tomonaga-Luttinger liquid (TLL) formalism. The advantage is that within this method all correlation functions are known and can be expressed in terms of power laws with non-universal, interaction dependent, exponents. To capture this situation we generalize a canonical Fowler-Northeim theory of field emission to solve the case of a barrier described by any power-law potential. With this generalization, expressed in terms of a confluent hypergeometric function, we are able to compute currents from arrays of carbon nanotubes. We shall present results showing an influence of various interaction terms, as encoded in varying TLL parameters, as well as effects of a finite temperature.

TT 45.5 Thu 10:30 HSZ 103

Delta-T noise for weak tunneling in one-dimensional systems: interactions versus quantum statistics — Gu Zhang[1], Igor V. Gornyi[2], and •Christian Spanslatt[3] — [1]Beijing Academy of Quantum Information Sciences, 100193 Beijing, China — [2]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany — [3]Department of Microtechnology and Nanoscience (MC2), Chalmers University of Technology, S-412 96 Göteborg, Sweden

Delta-T noise - excess charge noise at zero charge current but due to a finite temperature bias - has recently emerged as a novel transport spectroscopy tool for mesoscopic systems. In this talk, I present recent work [1] on delta-T noise for weak tunneling in one-dimensional, interacting systems. We show that the sign of the delta-T noise is generically determined by the scaling dimensions of the dominating tunneling process. Importantly, we clarify how this sign can be related to the quantum exchange statistics of the tunneling quasiparticles.

In systems with interacting and chiral channels, we find that when the delta-T noise is negative, the tunneling particles are boson-like, revealing their tendency towards bunching. Thus, one might expect that negative delta-T noise is a smoking gun for detecting "intrinsic anyons". Here, we find that this is not the case, since boson-like particles do not necessarily produce negative delta-T noise. Our findings clarify how delta-T noise can be used to probe the nature of collective excitations in interacting one-dimensional systems.

[1] G. Zhang, I. V. Gornyi, C. Spånslätt, PRB 105, 195423 (2022)

TT 45.6 Thu 10:45 HSZ 103

Terminable transitions in a topological fermion ladder — Yuchi He[1,2], Dante Kennes[2,3], Christoph Karrasch[4], and •Roman Rausch[4] — [1]Rudolf Peierls Centre for Theoretical Physics, Clarendon Laboratory, Parks Road, Oxford OX1 3PU, United Kingdom — [2]Institut für Theorie der Statistischen Physik, RWTH Aachen University and JARA - Fundamentals of Future Information Technology, 52056 Aachen, Germany — [3]Max Planck Institute for the Structure and Dynamics of Matter, Center for Free Electron Laser Science, 22761 Hamburg, Germany — [4]Technische Universität Braunschweig, Institut für Mathematische Physik, Mendelssohnstraße 3, 38106 Braunschweig, Germany

Interacting fermion ladders are important platforms to study quantum phases of matter including various Mott-insulators with different symmetry properties, such as the D-Mott and S-Mott phase. The latter hold pre-formed electron pairs and become paired liquids (d-wave and s-wave) upon doping. We show that the D-Mott and S-Mott phases are in fact two facets of the same topological phase and that the transition between them is terminable. With this, we provide a quantum analog of the well-known terminable liquid-gas transition. However, the phenomenology we uncover is even richer, as in contrast to the liquid-gas transition, the order of the transition can be tuned by the interaction and bears relevance for the topological properties of the system. The numerical results are obtained using the variational uniform matrix-product state (VUMPS) formalism, and are complemented by analytical field-theoretical explanations.

15 min. break

TT 45.7 Thu 11:15 HSZ 103

Critical and topological phases of a dimerized Kitaev chain in the presence of a quasiperiodic potential — •Saurabh Basu[1], Sk Noor Nabi[2], and Shilpi Roy[1] — [1]Department of Physics, Indian Institute of Technology Guwahati-Guwahati, 781039 Assam, India — [2]Department of Physics, Indian Institute of Technology Kharagpur, Kharagpur - 721302, West Bengal, India

We investigate the localization and topological properties of a dimerized Kitaev chain with p-wave superconducting correlations and a quasiperiodically modulated chemical potential. In the localization studies, we illustrate the existence of distinct phases, such as, the extended phase, the critical (intermediate) phase, and the localized phase that arise due to the competition between the dimerization and the onsite quasiperiodic potential. Most interestingly, the critical phase comprises of two distinct phase transitions that are found to exist between the extended to the localized phase, and between the critical (multifractal) and localized phases. Furthermore, we study the topological properties of the zero-energy edge modes via computing the real-space winding number and number of the Majorana zero modes present in the system. We specifically demonstrate that our model undergoes a phase transition from a topologically trivial to a non-trivial phase (topological Anderson phase) beyond a critical dimerization strength under the influence of the quasiperiodic potential strength. Finally, in presence of a large potential, we demonstrate that the system undergoes yet another transition from the topologically non-trivial to an Anderson localized phase.

TT 45.8 Thu 11:30 HSZ 103

Statistics induced phase transitions in the extended bosonic anyon Hubbard model — •Imke Schneider[1], Kevin Jägering[1], Martin Bonkhoff[1], Shijie Hu[2], Axel Pelster[1], and Sebastian Eggert[1] — [1]Department of Physics and Research Center Optimas, Technical University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Beijing Computational Science Research Center, Beijing 100193, China

We study a 1D extended Hubbard model of anyons with statistical exchange phases ranging from bosons to pseudo-fermions. The model can be realized in optical lattice experiments implementing occupation-dependent hopping amplitudes. We enforce a two-body hard-core constraint and numerically determine the full phase diagram including attractive on-site interactions. Surprisingly, the symmetry protected topological Haldane phase remains robust up to large statistical angles close to the pseudo-fermionic limit. However, for a critical angle the phase diagram qualitatively changes involving a dimer phase while the Haldane phase disappears. This behavior is analytically described by an adapted bosonization approach.

TT 45.9 Thu 11:45 HSZ 103

Fractonic Luttinger liquids and supersolids in a constrained Bose-Hubbard model — •Philip Zechmann[1,2], Ehud Altman[3], Michael Knap[1,2], and Johannes Feldmeier[1,2,4] — [1]Department of Physics, Technical University of Munich, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MC-QST), Schellingstr. 4, 80799 München, Germany — [3]Department of Physics, University of California, Berkeley, CA 94720 — [4]Department of Physics, Harvard University, Cambridge, MA 02138, USA

Quantum many-body systems with fracton constraints are widely conjectured to exhibit unconventional low-energy phases of matter. In this work, we demonstrate the existence of a variety of such exotic quantum phases in the ground states of a dipole-moment conserving Bose-Hubbard model in one dimension. For integer boson fillings, we perform a mapping of the system to a model of microscopic local dipoles, which are composites of fractons. We apply a combination of low-energy field theory and large-scale tensor network simulations to demonstrate the emergence of a novel dipole Luttinger liquid phase. At non-integer fillings our numerical approach shows an intriguing compressible state described by a quantum Lifshitz model in which charge density-wave order coexists with dipole long-range order and superfluidity - a 'dipole supersolid'. While this supersolid state may eventually be unstable against lattice effects in the thermodynamic limit, its numerical robustness is remarkable. We discuss potential experimental implications of our results.

TT 45.10 Thu 12:00 HSZ 103

Phase diagram detection via Gaussian fitting of number probability distribution — Daniele Contessi[1,2,3], Alessio Recati[1], and •Matteo Rizzi[2,3] — [1]Università di Trento & INO-CNR Pitaevskii BEC Center, Povo, Italy — [2]Peter-Grünberg-Institut 8, FZ Jülich, Germany — [3]Institute for Theoretical Physics, University of Cologne, Germany

In recent years, methods for automatic recognition of phase diagrams of quantum systems have gained large interest in the community: Among others, machine learning analysis of the entanglement spectrum has proven to be a promising route. Here, we discuss the possibility of using an experimentally readily accessible proxy, namely the number probability distribution that characterizes sub-portions of a quantum many-body system with globally conserved number of particles. We put forward a linear fitting protocol capable of mapping out the ground-state phase diagram of the rich one-dimensional extended Bose-Hubbard model: The results are quantitatively comparable with more sophisticated traditional numerical and machine learning techniques. We argue that the studied quantity should be considered among the most informative and accessible bipartite properties.

[1] D. Contessi, A. Recati, M. Rizzi, arXiv:2207.01478