TT 43: Correlated Electrons: Other Theoretical Topics

Time: Thursday 9:30–13:00 Location: H33

TT 43.1 Thu 9:30 H33

Fragility of local moments for singular hybridizations — •Max Fischer[1,2], Arianna Poli[3], Lorenzo Crippa[1,2], Sergio Ciuchi[3,4], Matthias Vojta[2,5], Alessandro Toschi[6], and Giorgio Sangiovanni[1,2] — [1]Universität Würzburg, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat — [3]Università dell'Aquila, Italy — [4]CNR, Italy — [5]TU Dresden, Germany — [6]TU Wien, Austria

Some transition-metal phtalocyanines on an Ag(001) surface show hybridizations for xz/yz-orbitals with sharp peaks superimposed on a rather constant z^2 contribution. These sharp peaks in the hybridization correspond to an Anderson impurity model with one impurity site hybridized with one bath site. Investigating only a constant hybridization this typically shows rich physics arising from the Kondo effect yielding local moments and screening of them at low temperatures. Expanding the constant hybridization by a peak at the Fermi level, the formation of the local moment is shifted to lower temperatures with increasing weight of the peak. With such a toy model we analyze the vanishing of the local moment at large weights of the peak. Here, we find the evolution from screening of the local moment to the formation of a singlet ground state for the two site AIM.

TT 43.2 Thu 9:45 H33

Inducing strong electronic correlation by charged impurities in weakly interacting two-dimensional electron system — Junho Bang[1], Byeongin Lee[1], João Augusto Sobral[2], Sayan Banerjee[2], Mathias Scheurer[2], •Jianfeng Ge[3], and Doohee Cho[1] — [1]Department of Physics, Yonsei University, Seoul 03722, Korea — [2]Institute for Theoretical Physics III, University of Stuttgart, 70550 Stuttgart, Germany — [3]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

When translational invariance is broken, e.g. in the presence of impurities, an ordered state can emerge where the electronic charge density modulates spatially. While conventional charge modulations are explained by weak-impurity scattering of Landau quasiparticles, strong correlations may drive the electrons to depart from the Fermi liquid behavior. Using scanning tunneling microscopy and spectroscopy, we switch the ionization state of individual surface impurities and discover a local phase transition induced by the impurity potential. A nanoscale charge-ordered phase, which breaks the symmetry of the underneath hosting lattice, spontaneously emerges from the otherwise uniform two-dimensional electron system. Further, the charge modulations appear with an anisotropy distinct from that of the Fermi surface, excluding any Fermi-surface-related interpretations for the ordered phase. While the exact origin of the solid-like electronic phase remains a mystery, our work demonstrates a microscopic approach for creating and manipulating strongly correlated electrons in two-dimensional systems even with weak intrinsic interactions.

TT 43.3 Thu 10:00 H33

Anomalous quantum oscillations from boson-mediated interband scattering — •Léo Mangeolle[1,2] and Johannes Knolle[1,2,3] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [3]Blackett Laboratory, Imperial College London, London SW7 2AZ, United Kingdom

Quantum oscillations (QO) in metals refer to the periodic variation of thermodynamic and transport properties as a function of inverse applied magnetic field. QO frequencies are normally associated with semi-classical trajectories of Fermi surface orbits but recent experiments challenge the canonical description. We develop a theory of composite frequency quantum oscillations (CFQO) in two-dimensional Fermi liquids with several Fermi surfaces and interband scattering mediated by a dynamical boson, e.g. phonons or spin fluctuations. Specifically, we show that CFQO arise from oscillations in the fermionic self-energy with anomalous frequency splitting and distinct strongly non-Lifshitz-Kosevich temperature dependencies. Our theory goes beyond the framework of semi-classical Fermi surface trajectories highlighting the role of many-body effects. We provide experimental predictions and discuss the effect of non-equilibrium boson occupation in driven systems.

TT 43.4 Thu 10:15 H33

Disentangling real space fluctuations: The diagnostics of metal-insulator transitions beyond single-particle spectral functions — •Michael Meixner[1], Marcel Krämer[1,2], Nils Wentzell[3], Pietro Bonetti[1,4], Sabine Andergassen[2], Alessandro Toschi[2], and Thomas Schäfer[1] — [1]Max-Planck-Insitut für Festkörperforschung, Stuttgart, Germany — [2]TU Wien, Vienna, Austria — [3]CCQ at Flatiron Institut, New York NY, USA — [4]Harvard University, Cabridge MA, USA

The destruction of metallicity due to the mutual Coulomb interaction of quasiparticles gives rise to fascinating phenomena of solid state physics such as the Mott metal-insulator transition and the pseudogap. A key observable characterizing their occurrences is the single-particle spectral function, determined by the fermionic self-energy. In this paper we investigate in detail how real space fluctuations constitute a self-energy that drives the Mott-Hubbard metal-insulator transition. To this aim we first introduce a real space fluctuation diagnostics approach to the Hedin equation, which connects the fermion-boson coupling vertex λ to the self-energy Σ. Second, by using cellular dynamical mean-field theory calculations for λ we identify the leading physical processes responsible for the destruction of metallicity across the transition. Eventually, to pave the way for relating our findings to the pseudogap phenomenology, we discuss the influence of real space fluctuations on the momentum-dependence of correlations.

TT 43.5 Thu 10:30 H33

Numerical indications for two-channel physics in the lightly doped t-J model — •Pit Bermes[1,2], Lukas Homeier[1,2], Sebastian Paeckel[1,2], Annabelle Bohrdt[2,3], and Fabian Grusdt[1,2] — [1]Department of Physics, Arnold Sommerfeld Center of Theoretical Physics, University of Munich, Theresienstrasse 37, 80333 Munich, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstrasse 4, 80799 München, Germany — [3]University of Regensburg, Universitätsstr. 31, Regensburg D-93053, Germany

The infamous cuprate superconductors at low doping are effectively described by hole doped antiferromagnets. Due to strong correlations however, standard techniques fail to describe these materials and full understanding of the microscopic mechanism remains elusive. Here we analyze numerical simulations of the lightly doped t-J model in two dimensions and present indications for two effective scattering channels in the simulated pair spectrum. We employ a previously proposed effective model whose degrees of freedom are given by magnetic polarons and bipolarons and show that it qualitatively reproduces the two branches in the pair spectrum. In addition, we propose a scheme to experimentally measure these signatures. The understanding of the effective quasiparticles presents an important step to unravel the elusive phases of high Tc superconductors.

TT 43.6 Thu 10:45 H33

Interplay of local and non-local electronic correlations in the Hubbard model — •Maria Chatzieleftheriou[1], Silke Biermann[2], and Evgeny Stepanov[2] — [1]Goethe University Frankfurt, Germany — [2]Ecole Polytechnique, IP Paris, France

Strongly correlated electronic systems exhibit intriguing properties and highly complex phase diagrams, including metal-to-insulator transitions, magnetic/charge orderings and the field's holy grail: high temperature superconductivity. Their theoretical description is very challenging and various many-body methods have been developed to this direction. I will present results using state-of-the-art numerical techniques that allow for an accurate description of both strong local electronic correlations and spatial fluctuations. I will discuss the application of this approach on the study of the Hubbard model, relevant for a series of materials, where we have analyzed the interplay of Mott physics and magnetic fluctuations at half-filling. We have identified the Slater and Heisenberg regimes in the phase diagram, which are separated by a crossover region of competing spatial and local electronic correlations. This bridging of the two limits (the spin-fluctuation dominated Slater regime at weak coupling and the Mott insulator at strong-coupling) had been a key missing ingredient to our understanding of metal-insulator transitions in real materials. Lastly, I will present recently obtained results on the evolution of the system's magnetic and charge susceptibility as a function of doping.

TT 43.7 Thu 11:00 H33

Fracton and topological order in the XY checkerboard toric code — Max Vieweg and •Kai Phillip Schmidt — Frichdrich-Alexander Universität Erlangen-Nürnberg (FAU), 91058 Erlangen, Germany

Topological and fraction phases are of great importance in current research due to their fascinating physical properties like entangled ground states, exotic excitations with non-trivial particle statistics or restricted mobility as well as potential applications in quantum technologies. The 2D toric code is the most paradigmatic, simplest, and exactly solvable model displaying topological order, which has been proposed as quantum memory and is relevant for quantum error correction. Consequently, the toric code plays an important role in several domains of research covering condensed matter physics, quantum optics, and quantum information.

However, the toric code has so far not been linked to the field of fracton physics. Here we introduce the XY checkerboard toric code (XYTC) connecting for the first time topological and fracton order in two dimensions within the same model. The XYTC represents a generalization of the conventional toric code with two types of star operators and two anisotropic star sublattices forming a checkerboard lattice. The quantum phase diagram is deduced exactly by a duality transformation displaying topological and type-I fracton phases.

15 min. break

TT 43.8 Thu 11:30 H33

Deconfinement Phase Transitions in a nematic two dimensional XY model with Long-range couplings — •Luis Walther[1], Josef Willsher[1,2], and Johannes Knolle[1,2,3] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstraße 4, 80799 Munchen, Germany — [3]Blackett Laboratory, Imperial College London, London SW7 2AZ, United Kingdom

The Modified XY model is an illustrative example of the interplay between ferromagnetic and nematic couplings, hosting both vortex and half-vortex excitations. The model gives rise to an exotic second order phase transition driven by the deconfinement of vortices into half-vortices. This transition is in the universality class of the Ising model, displaying features of the 'Deconfined Criticality' scenario. We analyse the effect of long-range algebraically decaying couplings $\sim r^{-2-\sigma}$ on the model. Long-range couplings enrichen the phase diagram and influence the deconfinement phase transition. We find that the transition persists for long-range couplings decaying fast enough so that $\sigma > 2-\eta$ holds, where η is the the correlation function exponent of the short-range XY model. Our results are based on Landau Peierls type arguments as well as Renormalisation Group flow techniques. Long-range couplings appear in many experimental setups including 2D Rydberg simulators. Therefore we hope our work contributes to enable the experimental observation of the deconfinement phase transition present in the model.

TT 43.9 Thu 11:45 H33

Mapping out Localization Phases in Bond-Disordered XXZ Models — Adrian Braemer[1], •Javad Vahedi[2], and Martin Gärttner[2] — [1]Physikalisches Institut, Universität Heidelberg, Im Neuenheimer Feld 226, 69120 Heidelberg, Germany — [2]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Historically, the phenomenon of many-body localization (MBL) has been studied in spin systems subject to random, local magnetic fields. At strong disorder, the system is found to be localized, with the local integrals of motion (LIOMs) consisting of single spins. However, this is not the only type of MBL: in bond-disordered Heisenberg models, the LIOMs have been shown to involve pairs of spins.

In this talk, we show that the bond-disordered XXZ model also exhibits a single-spin localized phase at strong anisotropy and map out the transitions between these three phases. To this end, we generalize the notion of occupation distance introduced by Hopjan et al. [1] to different observables, enabling us to characterize all three phases.

[1] Phys. Rev. B 104, 235112 (2021).

TT 43.10 Thu 12:00 H33

Melting of Devil's Staircases in the Long-Range Dicke-Ising Model — •Jan Alexander Koziol and Kai Phillip Schmidt — Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Staudtstraße 7, 91058 Erlangen, Germany

We present ground-state phase diagrams of the antiferromagnetic long-range Ising model under a linear coupling to a single bosonic mode on the square and triangular lattice. In the limit of zero coupling the ground state magnetization forms a Devil's staircase structure of magnetization plateaux as a function of an applied longitudinal field in Ising direction. The linear coupling to a single bosonic mode melts this structure to a so-called superradiant phase with a finite photon density in the ground state. The long-range interactions lead to a plethora of intermediate phases that break the translational symmetry of the lattice, as well as having a finite photon density. To study the ground-state phase diagram we apply an adaption of the unit-cell-based mean-field calculations [1,2], which capture all possible magnetic unit cells up to a chosen extent. Further, we exploit a mapping of the non-superradiant phases to the Dicke model in order to calculate upper bounds for phase transitions towards superradiant phases [3]. In the case of second-order phase transitions, these bounds agree with the boundaries determined by the mean-field calculations.

[1] J. A. Koziol et al., SciPost Phys. 14, 136 (2023);
[2] J. A. Koziol et al., SciPost Phys. 17, 111 (2024);
[3] A. Schellenberger et al., SciPost Phys. Core 7, 038 (2024).

TT 43.11 Thu 12:15 H33

Anyonic phase transitions in the 1D extended Hubbard model with fractional statistics — •Sebastian Eggert[1], Martin Bonkhoff[2], Kevin Jägering[1], Shi-Jie Hu[3], Axel Pelster[1], and Imke Schneider[1] — [1]University of Kaiserslautern-Landau — [2]Theoretische Physik, Univ. Hamburg — [3]Beijing Computational Science Research Center

Recent advances in quantum technology allow the realization of "lattice anyons", which have enjoyed large interest as particles which interpolate between bosonic and fermionic behavior. We now study the interplay of such fractional statistics with strong correlations in the one-dimensional extended Anyon Hubbard model at unit filling by developing a tailored bosonization theory and employing large-scale numerical simulations. The resulting quantum phase diagram shows several distinct phases, which show an interesting transition through a multicritical point. As the anyonic exchange phase is tuned from bosons to fermions, an intermediate coupling phase changes from Haldane insulator to a dimerized phase. Detailed results on the universality classes of the phase transitions are presented.

TT 43.12 Thu 12:30 H33

Nonlinear effects on the transport of fractional charges in quantum wires — •Imke Schneider[1], Flavia Braga Ramos[1], Rodrigo Gonçalves Pereira[2], and Sebastian Eggert[1] — [1]Physics Department and Research Center OPTIMAS, University of Kaiserslautern-Landau, Kaiserslautern, Germany — [2]International Institute of Physics and Departamento de Física Teórica e Ex- perimental, Universidade Federal do Rio Grande do Norte, Natal, Brazil

We investigate the transport properties of one-dimensional systems beyond linear response, focusing on the fractionalization of propagating charges. Starting from a right-moving unit charge, we predict its evolution into at least three distinct stable parts: a fractionally charged particle with freeparticle dynamics, a left-moving signal, and a right-moving low-energy excitation, which can carry positive or negative charge depending on the interaction strength and energy regime. Our findings provide deep insights into the universal correlated nature of these emergent particles and pave the way for out-of-equilibrium transport measurements, offering a direct method to extract the interaction parameters governing correlations in the system.

TT 43.13 Thu 12:45 H33

To Infinity and Back - $1/N$ Graph Expansion of Light-Matter Systems — •Andreas Schellenberger and Kai Phillip Schmidt — FAU Erlangen-Nürnberg, Erlangen, Deutschland

We present a method for performing a full graph expansion for light-matter systems, utilizing the linked-cluster theorem. This enables us to explore $1/N$ corrections to the thermodynamic limit $N \to \infty$, giving us access to the mesoscopic regime. This region is yet largely unexplored, as it is challenging to tackle with established solid-state methods. However, it hosts intriguing features, such as entanglement between light and matter that vanishes in the thermodynamic limit

[1-3]. We calculate physical quantities of interest for paradigmatic light-matter systems like generalized Dicke models by accompanying the graph expansion by both exact diagonalization (NLCE [4]) and perturbation theory (pcst++ [5]), benchmarking our approach against other techniques.

[1] J.Vidal, S.Dusuel, EPL 74, 817 (2006).
[2] K.Lenk, J.Li, P.Werner, M.Eckstein, arXiv:2205.05559 (2022).
[3] A.Kudos,D.Novokreschenov,I.Iorsh,I.Tokatly,arXiv:2304.00805(2023).
[4] M.Rigol, T.Bryant, R.R.P.Singh, PRL 97, 187202 (2006).
[5] L.Lenke, A.Schellenberger, K.P.Schmidt, PRA, 108 (2023).