TT 38: Superconductivity: Theory

Time: Friday 9:30–11:00 Location: H23

TT 38.1 Fri 9:30 H23

Unconventional superconductivity in the Hubbard model on the pyrochlore lattice — Shingo Kobayashi[1], Ankita Bhattacharya[2], •Carsten Timm[2], and Philip M. R. Brydon[3] — [1]RIKEN Center for Emergent Matter Science, Saitama, Japan — [2]TU Dresden, Germany — [3]University of Otago, Dunedin, New Zealand

The Hubbard model on the pyrochlore lattice is studied close to half filling. In the normal state, the band structure realizes a $j = 3/2$ semimetal. Remarkably, the repulsive Hubbard interaction leads to an *attractive* superconducting pairing interaction in the E_g channel, which allows a two-component order parameter, whereas the interaction is repulsive in the trivial A_{1g} channel. The attractive interaction relies on the fact that the E_g pairing avoids the detrimental on-site repulsion. The solution of the BCS gap equation shows that a time-reversal-symmetry-breaking superconducting phase is favored, which displays Bogoliubov Fermi surfaces.

TT 38.2 Fri 9:45 H23

Pairing instabilities of the Yukawa-SYK models with controlled fermion incoherence — •Wonjune Choi[1,2], Omid Tavakol[3], and Yong Baek Kim[3] — [1]Department of Physics, Technical University of Munich, 85748 Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 München, Germany — [3]Department of Physics, University of Toronto, Toronto, Ontario M5S 1A7, Canada

As a solvable platform of the strongly correlated superconductors, we study the pairing instabilities of the Yukawa-Sachdev-Ye-Kitaev (Yukawa-SYK) model, which describes spin-1/2 fermions coupled to bosons by the random, all-to-all Yukawa interactions. In contrast to the previously studied models, the random Yukawa couplings are sampled from a collection of Gaussian ensembles whose variances follow a continuous distribution rather than being fixed to a constant. By tuning the analytic behaviour of the distribution, we control the fermion incoherence to systematically examine various normal states ranging from the Fermi liquid to non-Fermi liquids that are different from the conformal solution of the SYK model with a constant variance. Using the linearised Eliashberg theory, we show that the onset of the unconventional spin-triplet pairing is preferred with the spin-dependent interactions. Although the interactions shorten the lifetime of the fermions in the non-Fermi liquid, the same interactions also dress the bosons to strengthen the tendency to pair the incoherent fermions. As a consequence, the onset temperature of the pairing is enhanced in the non-Fermi liquid compared to the case of the Fermi liquid.

TT 38.3 Fri 10:00 H23

Superconducting pairing from repulsive interactions of fermions in a flat-band system — Iman Mahyaeh[1], •Thomas Köhler[1], Annica M. Black-Schaffer[1], and Adrian Kantian[1,2] — [1]Department of Physics and Astronomy, Uppsala University, Sweden — [2]SUPA, Institute of Photonics and Quantum Sciences, Heriot-Watt University, Edinburgh EH14 4AS, United Kingdom

Many-body quantum systems of fermions with flat bands at the Fermi level are intensely studied for their potential to boost superconductivity by enhancement of the density of states. We use quasiexact numerical methods to show that repulsive interactions between spinless fermions in a model one-dimensional flat band system, the Creutz ladder, lead to a finite pairing energy that increases with repulsion. Pure repulsion however leaves charge-order as the dominant quasi-order over the superconductivity. Adding an additional attractive component to the interaction shifts the balance fully in favor of superconductivity. In this regime we find that the interactions of two flat bands further yields a remarkable enhancement to superconductivity far above and outside the known paradigms for one-dimensional fermions.

TT 38.4 Fri 10:15 H23

Degenerate plaquette physics as key ingredient of high-temperature superconductivity in cuprates — Mikhail Danilov[1], van Loon Erik G. C. P.[2], •Brener Sergey[1,3], Iskakov Sergey[4], Katsnelson Mikhail[5], and Lichtenstein Alexander[1,3] — [1]Institute of Theoretical Physics, University of Hamburg — [2]Department of Physics, Lund University — [3]The Hamburg Centre for Ultrafast Imaging — [4]Department of Physics, University of Michigan — [5]Radboud University, Institute for Molecules and Materials

A major pathway towards understanding complex systems is given by exactly solvable reference systems that contain the essential physics of the system. For the $t - t' - U$ Hubbard model, the four-site plaquette is known to have a point in the $U - \mu$ space where states with electron occupations $N = 2, 3, 4$ per plaquette are degenerate. Such a degenerate point causes strong fluctuations when a lattice of plaquettes is constructed. The next-nearest-neighbour hopping is shown to play a crucial role in the formation of strongly bound electronic bipolarons whose coherence at lower temperature could be the explanation for superconductivity. A complementary approach to the lattice of plaquettes is given by dual fermion perturbation theory starting from a single degenerate plaquette as a reference system. This perturbation theory already contains the relevant short-ranged fluctuations from the beginning via the two-particle correlations of the plaquette. We find that d-wave superconductivity remains a leading instability channel under a reasonably broad range of parameters.

TT 38.5 Fri 10:30 H23

Charge 4e skyrmion superconductivity? — •Gabriel Rein[1,2], Marcin Raczkowski[1], and Fakher F. Assaad[1,2] — [1]Institut für Theoretische Physik und Astrophysik Universität Würzburg, 97074 Würzburg, Germany — [2]Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, 97074 Würzburg, Germany

We consider a dynamically generated quantum spin Hall (QSH) state which has as characteristic that skyrmion excitations of the SO(3) order parameter carry charge $2e$. In Refs. [1,2] a model was defined with a single parameter λ that drives a continuous transition akin to deconfined quantum criticality from a QSH insulator to an s-wave superconductor via the condensation of charge $2e$ skyrmions. Our aim here is to modify this Hamiltonian by adding flavor degrees of freedom N_f, such that the charge of the skyrmion reads $N_f 2e$. In this talk we will map out the phase diagram of the model at $N_f = 2$. Although, to date charge $4e$ skyrmion superconductivity remains elusive, the phase diagram in the N_f versus λ plane is very rich with additional Kekule ordered phases.

[1] Y. Liu, Z. Wang, T. Sato, M. Hohenadler, C. Wang, W. Guo, and F. F. Assaad, Nat. Commun. 10 (2019) 2658
[2] Z. Wang, Y. Liu, T. Sato, M. Hohenadler, C. Wang, W. Guo, F. F. Assaad, Phys. Rev. Lett. 126 (2021) 205701

TT 38.6 Fri 10:45 H23

Groundstate phase diagrams of variants of the two-leg t-J ladder at low fillings — •Steffen Bollmann[1,2], Alexander Osterkorn[2], Elio König[1], and Salvatore R. Manmana[2] — [1]Max-Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]Institut for Theoretical Physics, Georg-August-University Göttingen, 37077 Göttingen, Germany

We study variants of the two-leg t-J ladder at low fillings using matrix product states (MPS) and perturbative approaches. While the groundstate phase diagram for the usual t-J ladder with spatially isotropic couplings at fillings $n > 0.5$ has been studied in detail, relatively little is known at low fillings. We address the phase diagram at these low fillings and investigate the influence of nearest-neighbor Coulomb interactions V and asymmetries in the spin-exchange $J_z \neq J_x = J_y$ on the size and nature of superconducting phases. For $V = 0$ the superconducting phase is enhanced, and we find a crossover within this phase from s-wave pairing to d-wave pairing when increasing the filling. For $J_z = 0$, the size of the superconducting region is reduced. In this talk, I will present the phase diagrams, discuss the physics, briefly introduce the methods used to classify the different phases, and give an outlook to possible realizations in experiments.