TT 14: Superconductivity: Theory 1

Time: Monday 15:00–18:15 Location: HSZ 204

Invited Talk TT 14.1 Mon 15:00 HSZ 204

Magnetotransport and 2D Superconductivity in Heterostructures of $BaBiO_3$ and $BaPbO_3$ — •German Hammerl — Experimental Physics VI, Center for Electronic Correlations an Magnetism, Institute of Physics, University of Augsburg, Germany

Perowskite-related $BaBiO_3$ is fascinating as it acts like a charge-density wave ordered insulator which becomes superconducing if homogeneously doped by, e. g., lead or potassium [1]. Furthermore it is theoretically predicted to be a topological insulator if electron or hole doped [2]. In this talk I will give an overview on this material and especially show that heterostructures of $BaBiO_3$ and $BaPbO_3$ show 2D superconductivity in agreement with a Berezinskiĭ-Kosterlitz-Thouless transition [3]. Temperature- and magnetic field-dependent sheet resistances are strongly affected by 2D quantum effects. Our analysis decodes the interplay of spin-orbit coupling, disorder and electron-electron interaction in this material [4].

[1] A. W. Sleight, *Phys. C* **514**, 152 (2015).
[2] B. Yan, M. Jansen, and C. Felser, *Nat. Phys.* **9**, 709 (2013).
[3] B. Meir, S. Gorol, T. Kopp, and G. Hammerl, *Phys. Rev. B.* **96**, 100507(R) (2017).
[4] P. Seiler, R. Bartel, T. Kopp, and G. Hammerl, *Phys. Rev. B* **100**, 165402 (2019).

TT 14.2 Mon 15:30 HSZ 204

Electron-lattice coupling and the superconductivity in hydrogen-rich systems — •Andrzej P. Kadzielawa[1,2], Andrzej Biborski[3], and Jozef Spalek[2] — [1]IT4Innovations, Vysoka skola banska - Technicka univerzita Ostrava, Ostrava, 17. listopadu 15/2172, 708 33 Ostrava-Poruba, Czech Republic — [2]Instyut Fizyki im. Mariana Smoluchowskiego, Uniwersytet Jagielloński, ulica Łojasiewicza 11, 30-348 Kraków, Poland — [3]Akademickie Centrum Materiałów i Nanotechnologii, AGH Akademia Górniczo-Hutnicza, Al. Mickiewicza 30, 30-059 Kraków, Poland

Recent development in the high-pressure physics provides us with a new class of the superconducting materials, namely with the hydrogen-rich materials, such as hydrogen sulphide ($T_c = 203\ K$ @ $150\ GPa$) or hydrogen lanthanide ($T_c = 274 - 286\ K$ @ $210\ GPa$).

We will discuss the versatility of the molecular-to-atomic transitions in one-, two-, and quasi-three-dimensional hydrogen systems, using our own original approach - the Exact Diagonalization Ab-Initio (EDABI) method. Starting from the extended Hubbard model, we examine an electron-correlation-driven conductivity connected with the creation of high-symmetry hydrogen molecular and atomic planes, as well as a series of both structural and electronic-in-nature quantum phase transitions. We obtain an effective electron-phonon Hamiltonian for which we estimate both the zero-point motion of the lattice ions, as well as of the electron-lattice coupling. Next, by using the McMillan formula we estimate the superconducting transition temperature versus the effective pressure (external and/or chemical).

TT 14.3 Mon 15:45 HSZ 204

Size of the Cooper pair in the Dynes superconductor — •Frantisek Herman — ETH, Zurich, Switzerland

After focusing on thermodynamic and spectroscopic properties considering role of the impurities on BCS superconductors within the Dynes phenomenology framework, here we turn to microscopic description of the underlying superconductive state. Within this talk, we provide detail analysis of the size of the Cooper pair as well as its underlying wave-function. We show that this length scale remains constant even at the critical disorder scattering, meanwhile the coherence length provided by the Ginzburg-Landau theory diverges, which shows that superconductor-metal transition driven by pair-breaking disorder occurs due to long-distance decoherence even when the Cooper pairs are locally stable. This mechanism is therefore very similar to the superconductor-metal transition driven by temperature. Presented analysis might be useful also from the point of view of preparing entangled state of electrons, since it deals with the pair-breaking as well as pair-conserving scattering rates effecting the size of the Cooper pair in different way.

TT 14.4 Mon 16:00 HSZ 204

The superconducting gap of the disordered NbAu compound from the Bogoliubov–de Gennes equations — •Bendegúz Nyári[1], Láaszló Szunyogh[1,2], and Balázs Újfalussy[3] — [1]Budapest University of Technology and Economics, Budapest, Hungary — [2]MTA-BME Condensed Matter Research Group, Budapest, Hungary — [3]Wigner-MTA, Budapest, Hungary

The screened Korringa–Kohn–Rostoker (SKKR) method provides a possible solution of the Bogoliubov–de Gennes equations for superconducting heterostructures and alloys. We discuss the case of the disordered NbAu compound within the coherent potential approximation (CPA). The limit of low Nb concentration can be interpreted as a model of isolated (superconducting) Nb impurities in a (non-superconducting) Au host. We calculate the local density of states (LDOS) for the components and we investigate the formation of the superconducting gap in the Nb DOS and spectral function as we increase the concentration of the Nb doping. We study the appearance of the gap and its evolution throughout the entire concentration range.We also compare the result with the calculation of a single Nb impurity embedded into Au.

TT 14.5 Mon 16:15 HSZ 204

Full-bandwidth Eliashberg theory of superconductivity beyond Migdal's approximation — •Fabian Schrodi, Alex Aperis, and Peter M. Oppeneer — Department for Physics and Astronomy, Uppsala University

We solve the anisotropic, full-bandwidth and non-adiabatic Eliashberg equations for electron-phonon mediated superconductivity by fully including the first vertex correction in the electronic self-energy. The non-adiabatic equations are solved numerically here without further approximations, for a one-band model system. We compare the results to those that we obtain by adiabatic full-bandwidth, as well as Fermi-surface restricted Eliashberg-theory calculations. We find that non-adiabatic contributions to the superconducting gap can be positive, negative or negligible, depending on the dimensionality of the considered system, the degree of non-adiabaticity, and the coupling strength. We further examine non-adiabatic effects on the transition temperature and the electron-phonon coupling constant. Our treatment opens a pathway to systematically study vertex correction effects in systems such as high-T_c, flat band and low-carrier density superconductors.

[1] arXiv:1911.12872.

TT 14.6 Mon 16:30 HSZ 204

Odd-frequency spin-triplet instability in disordered electron liquid — •Vladimir Zyuzin[1] and Alexander Finkel'stein[2] — [1]Texas A&M University, Nordita — [2]Texas A&M University

We theoretically consider a two-dimensional disordered conductor in the vicinity to the superconducting phase destroyed by a magnetic field. We find that a point of ending the superconductivity is a quantum critical point separating the conventional superconducting phase from a state with the odd-frequency spin-triplet superconducting pairing instability. We speculate that this could shed light onto a rather mysterious insulating state observed in the strongly disordered superconducting films in a broad region of magnetic fields.

15 min. break.

TT 14.7 Mon 17:00 HSZ 204

Quantitative Theory of Triplet Pairing in an Unconventional Superconductor — •Gabor Csire[1], Sudeep Ghosh[2], Balazs Ujfalussy[4], Martin Gradhand[3], James Annett[3], and Jorge Quintanilla[2] — [1]Catalan Institute of Nanoscience and Nanotechnology (ICN2), CSIC, BIST, Campus UAB, Bellaterra, Barcelona, 08193, Spain — [2]SEPnet and Hubbard Theory Consortium, School of Physical Sciences, University of Kent, Canterbury CT2 7NH, United Kingdom — [3]H. H. Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 1TL, United Kingdom — [4]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungarian Academy of Sciences, PO Box 49, H-1525 Budapest, Hungary

We report a first-principles based semiphenomenological approach to study the superconductivity in the centrosymmetric superconductor $LaNiGa_2$ which shows spontaneous magnetism in the superconducting state. Based on symmetry considerations it was already shown that the breaking of time-reversal symmetry is only compatible with nonunitary triplet pairing states in these crystals. We study different internally antisymmetric equal-spin triplet pairing models involving the first-principle band structure. We compare our predictions for the temperature dependence of the specific heat and it is found that it can be described by an interorbital equal-spin pairing on the nickel which breaks the time-reversal symmetry. It is shown that this pairing induces nodeless, two-gapped quasiparticle spectrum which resolves in spin space and leads to finite magnetisation due to the redistribution of Cooper pairs in spin space.

TT 14.8 Mon 17:15 HSZ 204

Triplet superconductivity in the frustrated Mott insulator Sn/Si(111) — Sebastian Wolf and •Stephan Rachel — School of Physics, University of Melbourne, Parkville, VIC 3010, Australia

Two-dimensional atom lattices on semiconductor substrates have been established as tailored realizations of the extended Hubbard model. They feature charge ordered and antiferromagnetic ground states. Most recently, the onset of superconductivity at 4.3 K has been reported in the hole-doped triangular lattice of tin atoms on a silicon substrate. Here we investigate the nature of the superconducting instability in hole-doped Sn/Si(111) by virtue of the weak-coupling renormalization group. While hexagonal lattices are known to prefer chiral d-wave pairing for their unconventional superconducting ground state, this is not the case for the particular band structure of Sn/Si(111) leading to a competition of the chiral d-wave and spin-triplet pairings. We show that – by taking into account non-local Coulomb interactions – the chiral d-wave is strongly suppressed resulting in odd-parity f-wave pairing for moderate hole-doping. For stronger hole-doping around 10%, as feasible in current experiments, the archetypal chiral p-wave superconductor is stabilized.

TT 14.9 Mon 17:30 HSZ 204

Unconventional superconductivity in non-centrosymmetric structures — •Tilman Schwemmer, Michael Klett, Domenico di Sante, Werner Hanke, and Ronny Thomale — Institut für Theoretische Physik und Astrophysik, Universität Würzburg

The pursuit of novel phases in correlated electron systems, such as possibly topological instances of unconventional superconductivity, must consider multiple energy scales including interaction strength, electronic band width, and, in particular, spin-orbit coupling (SOC). Furthermore the underlying crystal symmetries of a given system constrain the types of order that can be realized. While density functional theory and related ab initio techniques can provide a detailed description of a materials electronic structure that carefully accounts for the effects of SOC, it is necessary to additionally refine quantum many body techniques to study Fermi surface instabilities in the presence of SOC. Starting from a picture of itinerant electrons, we compute the effect of electronic correlations on the Fermi surface via renormalization group techniques. This allows us to study unconventional superconductivity arising from the interplay of SOC, Fermi surface topology, electronic correlations and crystal symmetries in real materials.

TT 14.10 Mon 17:45 HSZ 204

Eliashberg equations for an electron-phonon version of the Sachdev-Ye-Kitaev model: Pair Breaking in non-Fermi liquid superconductors — •Daniel Hauck[1], Markus Klug[1], Ilya Esterlis[2], and Jörg Schmalian[1,3] — [1]Institute for Theory of Condensed Matter, Karlsruhe Institute of Technology, Karlsruhe 76131, Germany — [2]Department of Physics, Harvard University, Cambridge, Massachusetts 02138, USA — [3]Institute for Solid State Physics, Karlsruhe Institute of Technology, Karlsruhe 76021, Germany

We present a theory that is a non-Fermi-liquid counterpart of the Abrikosov-Gor'kov pair-breaking theory due to paramagnetic impurities in superconductors. To this end we analyze a model of interacting electrons and phonons that is a natural generalization of the Sachdev-Ye-Kitaev-model. In the limit of large numbers of degrees of freedom, the Eliashberg equations of superconductivity become exact and emerge as saddle-point equations of a field theory with fluctuating pairing fields. In its normal state the model is governed by two non-Fermi liquid fixed points, characterized by distinct universal exponents. At low temperatures a superconducting state emerges from the critical normal state. We study the role of pair-breaking on T_c, where we allow for disorder that breaks time-reversal symmetry. For small Bogoliubov quasi-particle weight, relevant for systems with strongly incoherent normal state, T_c drops rapidly as function of the pair breaking strength before it vanishes at a critical pair-breaking strength via an essential singularity. The latter signals a breakdown of the emergent conformal symmetry of the non-Fermi liquid normal state.

TT 14.11 Mon 18:00 HSZ 204

Electron trimer states in conventional superconductors — •Ali Sanayei[1], Pascal Naidon[2], and Ludwig Mathey[1,3] — [1]Centre for Optical Quantum Technologies, Institute for Laser Physics, University of Hamburg — [2]RIKEN Nishina Centre, RIKEN — [3]The Hamburg Centre for Ultrafast Imaging, University of Hamburg

We expand the Cooper problem in a conventional superconductor by including a third electron in a higher empty band. This electron interacts with the other two electrons that are immersed in a Fermi sea of the lower band. We demonstrate that for sufficiently strong interband interactions the three electrons form a trimer state. We also show physical systems in which more than one trimer state can be formed.