TT 2: Focus Session: Exotic Charge Density Wave States of Matter: Correlations and Topology (joint session TT/HL)

The recent observation of charge density waves (CDW) in a variety of topological materials ranging from two-dimensional dichalcogenides, Weyl semimetals and metallic kagome systems has prompted intensive research on the origin and effects of such states. In these systems charge order forms the basis for correlated and topological states of quantum matter: Mott Hubbard correlations, tentative spin-liquid physics and chiral superconductivity in two-dimensional dichalcogenides, the emergence of axionic CDWs in Weyl semimetals and an interplay of Z2 topology, charge order and superconductivity in kagome metals. At the same time topology and electron correlations feed back on the CDW formation and dynamics. In this Focus Session we bring together theorists and experimentalists working in the field to discuss the interplay of charge order, correlations and topology in representative model systems, to identify major open challenges in our understanding of these systems and ultimately reach out for controlling CDW physics in correlated topological states of matter.

Organizers: Roser Valenti (Frankfurt University), Tim Wehling (Bremen University)

Time: Monday 10:00–12:45 Location: H7

TT 2.1 Mon 10:00 H7

Chiral superconductivity in the alternate stacking compound 4Hb-TaS$_2$ — •Amit Kanigel — Technion. Haifa, Israel

We study 4Hb-TaS$_2$, which naturally realizes an alternating stacking of 1T-TaS$_2$ and 1H-TaS$_2$ structures. The former is a well-known Mott insulator, which has recently been proposed to host a gapless spin-liquid ground state. The latter is a superconductor known to also host a competing charge density wave state. We find a superconductor with a T$_c$ of 2.7 Kelvin and anomalous properties, of which the most notable one is a signature of time-reversal symmetry breaking, abruptly appearing at the superconducting transition. This observation is consistent with a chiral superconducting state.

TT 2.2 Mon 10:30 H7

Non-local electronic correlations in 1T-TaS$_2$ out of equilibrium — •Uwe Bovensiepen — University of Duisburg-Essen, Faculty of Physics and Center for Nanointegration (CENIDE), 47048 Duisburg, Germany

Transition metal dichalcogenides with a d^1 transition metal electron configuration exhibit broken symmetry ground states and distorted structures. The formation of charge density wave (CDW) states in conjunction with Mott physics in 1T-TaS$_2$ is a well know example. Current efforts aim at microscopic understanding of the intertwined electronic and lattice effects. In this regard experiments in the time domain provide direct insights because the characteristically different timescales of electronic hopping with a time constant $\hbar/J \approx 2$ fs and the CDW amplitude period of 400 fs can be well distinguished. In this talk time-resolved photoelectron spectroscopy results will be presented in connection with theoretical results to discuss electronic excitations and their dynamics. Excitation and relaxation of doubly occupied sites is mediated by intersite hopping and coupling to delocalized electrons [1,2]. Comparison with literature indicates that such electron dynamics can be excited selectively, separate from lattice excitations. First experiments towards bulk sensitive, time-resolved photoelectron spectroscopy [3] will be discussed as well.

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[1] Ligges et al., PRL **120**, 166401 (2018)
[2] Avigo et al., PR Research **2**, 022046(R) (2020)
[3] Beyazit et al., PRL **125**, 076803 (2020)

15 min. break

TT 2.3 Mon 11:15 H7

Axionic charge density wave in the Weyl semimetal (TaSe$_4$)$_2$I — •Johannes Gooth — Max Planck Institut für Chemische Physik fester Stoffe, Dresden, Germany

An axion insulator is a correlated topological phase, which is predicted to arise from the formation of a charge-density wave in a Weyl semimetal that is, a material in which electrons behave as massless chiral fermions. The accompanying sliding mode in the charge-density-wave phase - the phason - is an axion and is expected to cause anomalous magnetoelectric transport effects. However, this axionic charge-density wave has not yet been experimentally detected. Here, we report the observation of a large positive contribution to the magnetoconductance in the sliding mode of the charge-density-wave Weyl semimetal (TaSe$_4$)$_2$I for collinear electric and magnetic fields. The positive contribution to the magnetoconductance originates from the anomalous axionic contribution of the chiral anomaly to the phason current, and is locked to the parallel alignment of the electric and magnetic fields. By rotating the magnetic field, we show that the angular dependence of the magnetoconductance is consistent with the anomalous transport of an axionic charge-density wave. Our results show that it is possible to find experimental evidence for axions in strongly correlated topological condensed matter systems, which have so far been elusive in any other context.

Invited Talk TT 2.4 Mon 11:45 H7

Electronic instabilities of kagomé metals and density waves in the AV$_3$Sb$_5$ materials — •Leon Balents — University of California, Santa Barbara

Recently, a new class of kagomé metals, with chemical formula AV$_3$Sb$_5$, where A = K, Rb, or Cs, have emerged as an exciting realization of quasi-2D correlated metals with hexagonal symmetry. These materials have been shown to display several electronic orders setting in through thermodynamic phase transitions: multi-component (*3Q*) hexagonal charge density wave (CDW) order below a T$_c$ of 90K, and superconductivity with critical temperature of 2.5K or smaller, and some indications of nematicity and one-dimensional charge order in the normal and superconducting states. Other experiments show a strong anomalous Hall effect, suggesting possible topological physics. I will discuss a theory of these phenomena based in part on strong interactions between electrons at saddle points, as well as ideas related to different competing density wave orders.

TT 2.5 Mon 12:15 H7

Charge density waves and superconductivity in kagome metals — •Titus Neupert — Univertity of Zurich, Zurich, Switzerland

Strongly correlated itinerant electron systems exhibit an intertwining of interactions and electronic band fermiology, including flat bands and van Hove points with diverging density of states, nesting patterns, or band degeneracies –for instance of Dirac type or quadratic band touching. The kagome lattice stands out in that it combines all these characteristics, and has thus been subject to many theoretical investigations. However, material realizations of kagome metals with interaction-induced Fermi instabilities have largely been elusive. The recently discovered family of kagome materials AV3Sb5 has filled this gap, displaying charge ordered and superconducting phases with unconventional properties. In my talk, I will discuss the status quo understanding of these instabilities emanating from a critical synopsis of experiments and theoretical studies.