DS 5: Focus Session: Tunable Correlations in van der Waals Quantum Materials II (joint session TT/DS/HL)

Time: Tuesday 9:30–10:45 Location: HSZ/0105

Invited Talk DS 5.1 Tue 9:30 HSZ/0105

Simulating high-temperature superconductivity in a triangular moiré lattice — •Kin Fai Mak — Luruper Chaussee 149 Bldg. 900 (MPSD), 22761 Hamburg, Germany

Moiré materials built on transition metal dichalcogenide semiconductors have emerged as a tunable platform for simulating the Hubbard model on a triangular lattice. A natural question arises: Can the platform be tuned to yield a phase diagram similar to that in high-temperature cuprate superconductors? In this talk, I will discuss the emergence of high-temperature superconductivity near the Mott transition in a triangular moiré lattice with intermediate coupling strength. The emergent doping-temperature phase diagram looks remarkably similar to that in cuprate superconductors. I will also discuss the evolution of the phase diagram by tuning the band structure of the material by gating. The results could provide a new angle for understanding the phenomenon of high-temperature superconductivity in strongly correlated materials.

DS 5.2 Tue 10:00 HSZ/0105

Engineering Hubbard models with gated two-dimensional moiré systems — •Yiqi Yang[1], Yubo Yang[2], Miguel Morales[3], and Shiwei Zhang[3] — [1]Lund University, Lund, Sweden — [2]Hofstra University, New York, USA — [3]Flatiron Institute, New York, USA

Lattice models are powerful tools for studying strongly correlated quantum many-body systems, but their general lack of exact solutions motivates efforts to simulate them in tunable platforms. Recently, a promising new candidate has emerged for such platforms from two-dimensional materials. A subset of moiré systems can be effectively described as a two-dimensional electron gas (2D EG) subject to a moiré potential, with electron-electron interactions screened by nearby metallic gates. In this talk, we present the realization of lattice models in such systems [1]. We show that, by controlling the gate separation, a 2D EG in a square moiré potential can be systematically tuned into a system whose ground state exhibits orders analogous to those of the square lattice Hubbard model, including the stripe phase. Furthermore, we study how variations in gate separation and moiré potential depth affect the ground-state orders. A number of antiferromagnetic phases, as well as a ferromagnetic phase and a paramagnetic phase, are identified.We then apply our quantitative downfolding approach to triangular moiré systems closer to current experimental conditions, compare them with the square lattice parameters studied, and outline routes for experimental realization of the phases.
[1] arXiv:2508.13314

DS 5.3 Tue 10:15 HSZ/0105

Dirac quantum criticality in twisted double bilayer transition metal dichalcogenides — •Jan Biedermann and Lukas Janssen — Institut für Theoretische Physik and Würzburg-Dresden Cluster of Excellence ct.qmat, Technische Universität Dresden, 01062 Dresden, Germany

We investigate the phase diagram of twisted double bilayer transition metal dichalcogenides with ABBA stacking as a function of twist angle and pressure. At a filling of 2 holes per moiré unit cell, the noninteracting system hosts a Dirac semimetal with graphene-like low-energy bands. At small twist angles however, interactions dominate the low-temperature physics, stabilizing an antiferromagnetic insulating ground state that is characterized by spin density modulations at the moiré scale. The twist-tuned semimetal-to-antiferromagnet transition is shown to be continuous and belongs to the Gross-Neveu-Heisenberg universality class. We propose that this transition may also be realized by applying uniaxial pressure to a sample, raising the intriguing possibility of experimentally measuring the associated critical exponents for the first time.

DS 5.4 Tue 10:30 HSZ/0105

Chemically Tunable Correlation Strength in Breathing Mode Kagome van der Waals Materials Nb_3(F,Cl,Br,I)$_8$ — •Joost Aretz[1], Sergii Grytsiuk[1], Xiaojing Liu[2], Giovanna Feraco[2], Chrystalla Knekna[2,3], Muhammad Waseem[2], Zhiying Dan[2], Marco Bianchi[4], Philip Hofmann[4], Mazhar Ali[5], Mikhail Katsnelson[1,6], Antonija Grubišić-Čabo[2], Hugo Strand[7], Erik van Loon[8], and Malte Rösner[1,9] — [1]Radboud University, Nijmegen, Netherlands — [2]University of Groningen, Netherlands — [3]University of Amsterdam, Netherlands — [4]Aarhus University, Denmark — [5]Delft University of Technology, Netherlands — [6]Constructor University, Bremen, Germany — [7]Örebro University, Sweden — [8]Lund University, Sweden — [9]Bielefeld University, Germany

Finding tunable correlated electron systems in nature is highly desirable for studying strongly correlated materials. Our recent work demonstrates that the Nb_3X_8-family offers such a platform for tuning correlation effects in van der Waals systems. By using ab initio downfolding and cluster dynamical mean-field theory we show how correlation effects evolve across the halide series. In these materials an intruiging interplay between in-plane trimerization and out-of-plane dimerization leads to correlated insulating behavior, where the strength of correlations can be tuned by switching the halide or by changing the layer number. The predicted trends are supported by ARPES measurements. The correlated electron physics in this system is robust, tunable and layered, which allows studying the role of correlations in devices such as the $NbSe_2/Nb_3Br_8$ Josephson diode.