Symposium Quantum 2D-Moiré and Rhombohedral van-der-Waals Systems (SYWS)

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Recent advancements in the field of 2D-Moiré and rhombohedral van-der-Waals systems have significantly enriched the landscape of quantum materials. These versatile platforms allow the creation and control of flat bands and enable tunable quantum phase diagrams – critical for advancing quantum technologies. The tuning of flat bands, either through precise control of the Moiré angle or by introducing an external electric field, has enabled the discovery of various emergent phenomena such as (fractional) Chern insulators, ultrafast exciton dynamics, and superconductivity. The symposium will showcase complementary experimental and theoretical approaches to uncover and control such complex electronic states in novel van-der-Waals heterostructures.

Overview of Invited Talks and Sessions

(Lecture hall ZHG008)

Invited Talks

SYWS 1.1	Thu	10:45–11:15	ZHG008	**Twisted transition metal dichalcogenides for new topological states** — •Jie Shan
SYWS 1.2	Thu	11:15–11:45	ZHG008	**Exciton dynamics in 2D-moiré materials in space and time** — •Stefan Mathias
SYWS 1.3	Thu	11:45–12:15	ZHG008	**Fractional Quantum Anomalous Hall Effect and Chiral Superconductivity in Graphene** — •Long Ju
SYWS 1.4	Thu	12:15–12:45	ZHG008	**Electron Correlations in Moiré vs. Moiréless Quantum Matter** — •Tim Wehling

Sessions

SYWS 1.1–1.4	Thu	10:45–12:45	ZHG008	**Quantum 2D-Moiré and Rhombohedral van-der-Waals Systems**

SYWS 1: Quantum 2D-Moiré and Rhombohedral van-der-Waals Systems

Time: Thursday 10:45–12:45 Location: ZHG008

Invited Talk SYWS 1.1 Thu 10:45 ZHG008

Twisted transition metal dichalcogenides for new topological states — •Jie Shan — Max Planck Institute for the Structure and Dynamics of Matter — Cornell University

Moiré materials provide a highly controllable platform to explore electronic correlations and topology. Specifically, flat Chern bands have been predicted in twisted transition metal dichalcogenide bilayers such as MoTe2 and WSe2. In this talk, I will discuss recent experimental observations of the integer and fractional quantum Hall effects in twisted MoTe2 under zero magnetic field. I will also present evidence of a fractional topological insulator with each helical edge contributing 3/2 conductance quantum (e^2/h) in 2.1-degree-twisted MoTe2.

Invited Talk SYWS 1.2 Thu 11:15 ZHG008

Exciton dynamics in 2D-moiré materials in space and time — •Stefan Mathias — I. Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen, Germany

In 2D semiconducting quantum materials, organic semiconductors and their heterostructures, the energy of absorbed light is stored in Coulomb-bound electron-hole pairs, i.e. excitons. For future technological applications of these classes of materials, for instance in optoelectronics and for energy harvesting, it is crucial to study the initial light-matter interaction and the subsequent relaxation and dissipation processes at the fundamental level [1] and on the relevant length and time scales [2].

I will present the ultrafast formation dynamics of bright and dark excitons in different moiré materials in space and time [3]. In particular, I will report on the identification of a key signature of the moiré superlattice that is imprinted on the momentum-resolved interlayer exciton photoemission signal [4,5]. Furthermore, I will present photoemission exciton tomography [6] that allows us to study ultrafast charge transfer from TMD to organic layers, and to disentangle multiorbital contributions in the exciton formation in the 2D moiré - organic semiconductor heterostructures.

References: [1] Merboldt et al., Nature Physics (2025). [2] Schmitt et al., Nature Photonics 19, 187 (2025). [3] Reutzel et al., Adv. in Phys. X 9,, 2378722 (2024) [4] Schmitt et al., Nature 608, 499 (2022). [5] Bange et al., Science Adv. 10, eadi1323 (2024). [6] Bennecke et al., Nature Comm. 15, 1804 (2024).

Invited Talk SYWS 1.3 Thu 11:45 ZHG008

Fractional Quantum Anomalous Hall Effect and Chiral Superconductivity in Graphene — •Long Ju — MIT, Cambridge, Massachusetts, USA

Condensed matter physics has witnessed emergent quantum phenomena driven by electron correlation and topology. Two prominent examples are Fractional Quantum Hall Effect and Superconductivity. In this talk, I will show how these two disparate phenomena can be unified in the simplest carbon material: a crystalline stacking order of graphene called rhombohedral stacking. Not only it can exhibit both fractional and superconducting electron physics, we observed both with a twist: the FQHE happens at zero magnetic field, therefore Fractional Quantum Anomalous Hall Effect; the superconductor is a magnet by itself, therefore Chiral Superconductor. I will discuss the origin of these states and their implications for fundatmental physics studies and topological quantum computation.

Invited Talk SYWS 1.4 Thu 12:15 ZHG008

Electron Correlations in Moiré vs. Moiréless Quantum Matter — •Tim Wehling — I. Institute of Theoretical Physics, University of Hamburg, 22607 Hamburg, Germany — The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

Understanding and controlling electron correlations in quantum matter remains a central challenge in materials science. In recent years, a wide range of novel correlated states has been discovered through the precise stacking and twisting of two-dimensional van der Waals materials. These stacked structures uniquely give rise to correlated phases that are not predictable from the properties of the individual layers alone.

In this talk, we compare electron correlations, as well as spin, valley, and superconducting order, in twisted graphene systems [1, 2] and twisted transition metal dichalcogenide multilayers [3] with those in moiréless systems - i.e., non-twisted graphene multilayers [4], doped fullerides [5], and functionalized graphene, where correlations arise at the atomic scale [6]. We discuss how multi-orbital physics, flat bands, and quantum geometry govern the emergence of electronic phases in these systems.

[1] G. Rai et al., Phys. Rev. X 14, 031045 (2024).
[2] H. Hu et al., Phys. Rev. Lett. 131, 166501 (2023).
[3] A. Fischer et al., arXiv:2412.14296.
[4] A. Fischer et al., Phys. Rev. Res. 6, L012003 (2024).
[5] N. Witt et al., Npj Quantum Mater. 9, 1 (2024).
[6] N. Witt et al., arXiv:2503.03700.