Curriculum vitae

Personal information

Name	Tobias Markus Raphael Wolf
ORCID	0000-0003-4665-9874
Date of birth	August 16, 1991
Nationality	German

Employment and work experience

Fall 2021 – now	**Postdoctoral researcher** Center for Complex Quantum Systems, The University of Texas at Austin Supervisor: Prof. Dr. Allan MacDonald
April 2016 – Fall 2021	**Researcher and teaching assistant** Institute for Theoretical Physics, ETH Zürich, Switzerland Supervisor: Prof. Dr. Gianni Blatter
Sept 2014 – March 2016	**Teaching assistant** (see teaching activities) ETH Zürich, Switzerland Supervisors: Profs. E. Kowalski, H. Knörrer, J. Teichmann, C. Degen

Fellowships and awards

Fall 2021 – Fall 2023	**PostDoc.Mobility SNSF fellowship (Grant No. 203152)** Swiss National Science Foundation (SNSF) Project: Quantum engineered van der Waals materials

Education

April 2016 – Spring 2021	**Doctor of Sciences ETH in Physics** ETH Zürich, Switzerland Thesis advisors: Prof. Dr. Gianni Blatter and Prof. Dr. Oded Zilberberg Thesis: Electronic properties of twisted-layer graphene systems Defense date: December 11, 2020
Sept 2014 – March 2016	**Master of Science ETH in Physics** ETH Zürich, Switzerland. Diploma with distinction.
Sept 2011 – Sept 2014	**Bachelor of Science ETH in Physics** ETH Zürich, Switzerland. Diploma with distinction.
Sept 2002 – July 2011	**Secondary school (Gymnasium)** Klettgau Gymnasium Tiengen, Germany. Abitur degree with distinction.

Teaching activities

Sept 2016 – March 2021	**Teaching assistant at the Institute for Theoretical Physics, ETH Zürich** Courses: Statistical physics (2016, 2018, 2020), Quantum mechanics I and II (2017, 2019), Electrodynamics (2018, *VMP Assistant award*), Solid state theory (2020)

Sept 2013 – June 2016	**Teaching assistant for D-MATH and D-PHYS, ETH Zürich** Courses: Analysis I and II (2 years), Physics I and II (1 year)

Advising junior researchers

Master students

- Jacob MacWilliams, Semester project "Magnetism in doped twisted-bilayer graphene", Summer 2023–Spring 2024, University of Konstanz, supervised by Prof. Oded Zilberberg.
- Nader Mostaan, Semester project "Dirac-like fermions in a moiré-induced square potential", Fall 2019, ETH Zürich, supervised by Prof. Oded Zilberberg.
- Philippe Suchsland, Semester project "Designing superstructures with Dirac Fermions", Spring 2019, ETH Zürich, supervised by Prof. Oded Zilberberg.

Memberships

- MaNEP Switzerland Network
- American Physical Society

Personal skills

Programming

- Scientific computing with julia and python (Numpy, Scipy, Matplotlib, etc), symbolic calculations with Mathematica, typesetting with latex.
- Basic knowledge using cloud environments (e.g., AWS EC2)
- Experience with terminal and version management (git, gitlab, github)
- Basics in C++ and Fortran

Software	Adobe Illustrator, Microsoft Office, Blender
Languages	German *(native)*, English *(proficient)*

Major scientific achievements

My field of expertise is the condensed matter theory for the electronic properties of van der Waals materials, in particular graphene-based multilayers and the effect of twist-induced moiré superlattices. In what follows, I give an overview over my three major contributions to the field of twisted-layer graphene systems in the context of band topology, flat bands and strong correlations.

My first achievement is to fully classify the possible electronic spectra in the van der Waals material formed by monolayer graphene on hexagonal boron nitride (hBN), and to provide a 'treasure map' that allows to engineer a non-trivial valley topological insulator [TW1]. While the effective continuum model had been studied for specific substrate models, my work was the first to explore the full 6-dimensional parameter space that consistently describes the substrate potential in terms of its symmetries. To this end, I determined the conditions for band inversions using analytical degenerate perturbation theory. I determined and analyzed the Berry curvature of three-band hybridizations which can be distinctly different from two-band splittings. Most importantly, I not only highlight interesting parameter regimes with unusual valley Chern numbers, but I also provide a practical and experimentally useful guide of how each model parameter can be engineered in practice through gate-patterning, strain- and substrate-engineering.

My second achievement is the prediction of novel flat bands and spontaneous magnetism in twisted bilayer graphene [TW2] doped away from charge neutrality and at a twist angle $\theta^\star \simeq 0.8^\circ$, i.e., below the magic angle. In particular, I used a Hartree-Fock mean field analysis on a tight-binding model to show that electronic interactions at half-filling of the flat band promote moiré-periodic arrays of magnetic moments that tend to coalign. Remarkably, these magnetic correlations are tunable by applying a transverse electric field. I identified the electrically induced Berry-flux texture as the origin of this tunability that leads to enhanced band dispersion. This effect is potentially useful for applications and absent in magic-angle flat bands.

My third and most recent achievement is to study the combination of twisted bilayer graphene with magnetic materials and to engineer flat bands with novel correlations in the valley degree of freedom [TW3]. The twist-engineered flat bands in such materials are spin hybridized due to proximity-induced spin–orbit coupling and magnetic exchange fields, but nearly degenerate in valley. In my work, I used a Hartree-Fock mean field analysis to predict that electron–electron interactions promote spirals in the valley degree of freedom. I interpreted this effect as spontaneous valley mixing and proposed experimental signatures for valley Hall devices. I derived a low-energy valley-Heisenberg model and showed how the interaction-induced valley correlations are modified by transverse electrical fields. With these results, I introduced a new engineered material in which novel nontrivial valley physics is promoted over spin physics.

References

[TW1] T. M. R. Wolf, O. Zilberberg, I. Levkivkskyi, G. Blatter, I. Levkivskyi, and G. Blatter, "Substrate-induced topological minibands in graphene", Phys. Rev. B **98**, 125408 (2018), arXiv:1805.10670.

[TW2] T. M. R. Wolf, J. L. Lado, G. Blatter, and O. Zilberberg, "Electrically Tunable Flat Bands and Magnetism in Twisted Bilayer Graphene", Phys. Rev. Lett. **123**, 096802 (2019), arXiv:1905.07651.

[TW3] T. M. R. Wolf, O. Zilberberg, G. Blatter, and J. L. Lado, "Spontaneous Valley Spirals in Magnetically Encapsulated Twisted Bilayer Graphene", Phys. Rev. Lett. **126**, 056803 (2021).