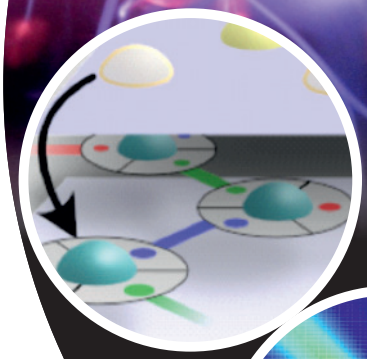
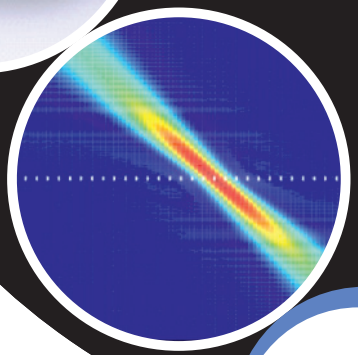
Workshop on correlated
condensed quantum matter

Correlations in Novel Quantum Materials

July 24–28, 2023 • Stuttgart, Germany

Max Planck Institute for Solid State Research





Program Details

ICAM-I2CAM
Institute for Complex Adaptive Matter

Further information at

www.fkf.mpg.de/cnqm2023

Public interdisciplinary panel discussion:

The Future of Solid State Research

Organizing Committee

MPI for Solid State Research

Laura Classen
Elio J. König
Thomas Schäfer

Contact
CNQM2023@fkf.mpg.de

Max Planck Institute for Solid State Research

Site Map

Floor 3 Room A4 and Room B3

Changing Table
Floor 2 Room M2 and Room M4

Scope

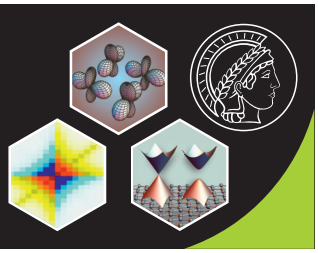
Materials with strongly correlated quantum particles are at the forefront of present solid state research. Understanding the experimental properties of novel quantum materials crucially relies on the application of cutting-edge analytical and numerical tools.

This workshop aims at bringing together world-leading experts to advance the current perspective on important questions of the field: What are the signatures of quantum order in newly synthesized experimental setups? Which aspects of quantum materials can be described on the model level? What are the computational and algorithmic boundaries hindering the solution of the many-body problem? What is the nature of phase transitions between these novel states of matter?

Program

Monday, July 24, 2023

Lecture Hall 2D5

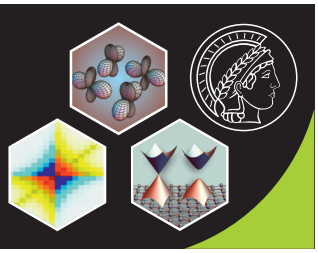


CEDT AM 08:00	**Registration**
08:45	**Laura Classen, Elio König and Thomas Schäfer** Max Planck Institute for Solid State Research, Stuttgart **Welcome**
	Session 1 Unconventional Superconductors and Intertwined Phases
09:00	**Andrey Chubukov** University of Minnesota **Superconductivity near spin and valley orders in Bernal bilayer graphene**
09:45	**Anna Seiler** University of Göttingen **Correlated phases in the vicinity of tunable van Hove singularities in Bernal bilayer graphene**
10:15	Coffee Break
10:45	**Srinivas Raghu** Stanford University **Reentrant superconductivity and multiple superconducting phases of UTe_2**
11:15	**Alex Levchenko** University of Wisconsin-Madison **Quantum transport from fluctuations near the end point of superconducting dome**
11:45	**Poster Ads**
CEDT PM 12:15	Lunch Break
01:15	**Discussion**
	Session 2 Emergent Quasiparticles: Yes or no?
02:00	**Roderich Moessner** MPI-PKS Dresden **Progress in 3d quantum spin liquids**
02:45	**Johannes Reuther** FU Berlin **Quantum Effects on Unconventional Pinch Point Singularities**
03:15	Coffee Break
03:45	**Felix Baumberger** University of Geneva **The fate of quasiparticles beyond the Fermi liquid phase of Sr_2RuO_4**
04:15	**Mengxing Ye** University of Utah **Location and thermal evolution of the pseudogap due to spin fluctuations**
04:45	**Poster Ads**
05:30	**Poster Session**

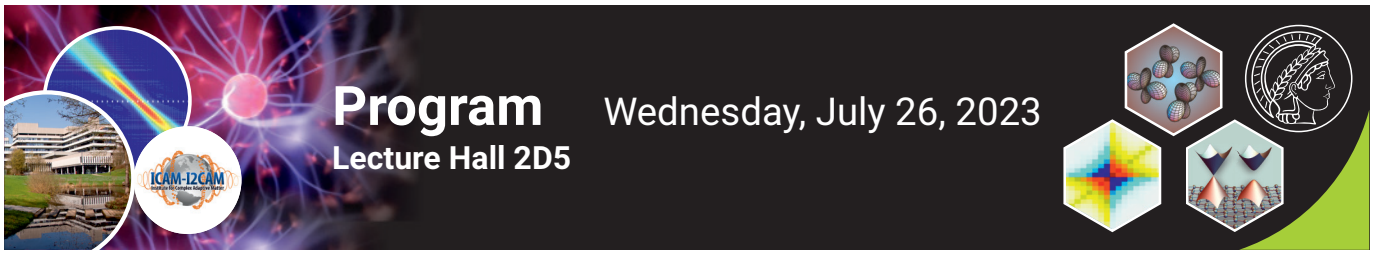
Program

Lecture Hall 2D5

Tuesday, July 25, 2023



	Session 3	**Strong Correlations: from Models to Materials**
09:00	**Antoine Georges** Collège de France, Paris and CCQ-Flatiron Institute, New York **What Do We Know Today about the 2D Hubbard model?**	
09:45	**Jan von Delft** Ludwig-Maximilians-Universität, Munich **Fermi surface reconstruction and strange metal behavior at a heavy fermion quantum phase transition**	
10:15	Coffee Break	
10:45	**Emanuel Gull** University of Michigan, Ann Arbor **Let's get real – Adapting the toolkit of many-body theory to realistic materials simulation**	
11:15	**Matthieu Le Tacon** IQMT KIT **Novel phenomena and perspectives in 3d- and 5d- transition metal compounds**	
11:45	Lunch Break	
CEDT PM 01:15	**Discussion**	
	Session 4	**Multiorbital Effects in Strongly Correlated Systems**
02:00	**Piers Coleman** Center for Materials Theory, Physics and Astronomy, Rutgers University Department of Physics, Royal Holloway University London **Spin: stem-cell for emergence in quantum materials.**	
02:45	**Massimo Capone** SISSA **Electron-phonon interaction and strong correlations in multi-orbital systems: Competition or cooperation?**	
03:15	Coffee Break	
03:45	**Silke Bühler-Paschen** TU Wien **Strange metal behavior in heavy fermion compounds and beyond**	
04:15	**Premala Chandra** Rutgers University **Light-Induced Transitions in Quantum Paraelectrics**	
04:45	**Free Discussion**	
06:00	**Public interdisciplinary panel discussion: The Future of Solid State Research** Prof. Piers Coleman, Prof. Martin Dressel, Prof. Antoine Georges, Prof. Bettina V. Lotsch	

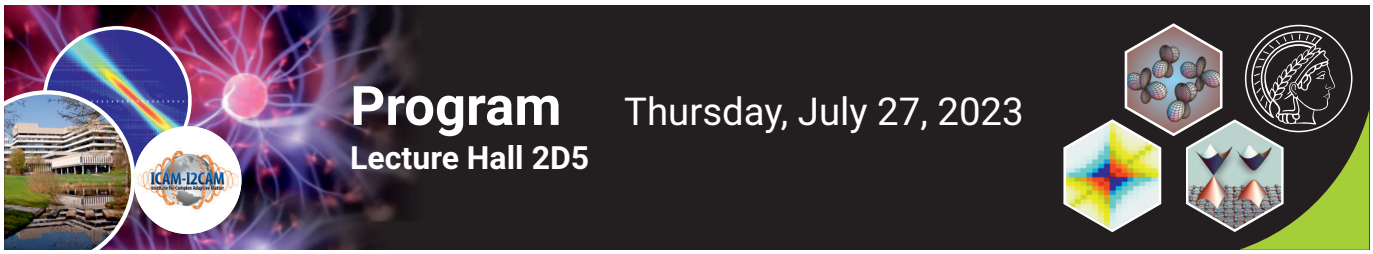


Program

Lecture Hall 2D5

Wednesday, July 26, 2023

	Session 5	Quantum Information and Dynamics
09:00	**Dmitry Abanin** University of Geneva **Probing non-equilibrium quantum matter with quantum processors**	
09:45	**Igor Boettcher** University of Alberta **Topological Hyperbolic Matter on A Circuit Board**	
10:15	Coffee Break	
10:45	**Peter P. Orth** Saarland University **Nonlinear interrogation of quantum materials: why higher order response tells you more**	
11:15	**Vadim Oganesyan** City University New York **Quantum annealing with AC field**	
11:45	Lunch Break	
CEDT PM 01:15	**Discussion**	
01:00	Meeting point in front of the main entrance	**Departure Excursion**
05:00	**Workshop Discussion "The Future of Solid State Research"**	
06:00	**Conference Dinner** **Trödler zur Burgschenke, Esslingen am Neckar** Return Excursion	
9:00	**Free Discussion**	



Program

Lecture Hall 2D5

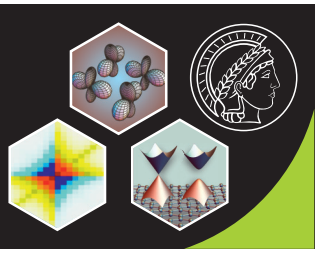
Thursday, July 27, 2023

	Session 6	Mott is Different
09:00	**Roser Valentí** University of Frankfurt **On heavy fermions and doped Mott physics in two-dimensional van der Waals platforms**	
09:45	**Luca de' Medici** ESPCI Paris **Mott Quantum Critical Points and phase separation at finite doping in Hund metals**	
10:15	Coffee Break	
10:45	**Lucia Reining** LSI, CNRS/École Polytechnique **Some thoughts about perturbation theory**	
11:15	**Alessandro Toschi** TU Wien **Characteristic Timescales and Longterm-Memory Effects in Correlated Many-Electron Systems**	
11:45	Lunch Break	
CEDT PM 01:15	**Discussion**	
	Session 7	**Topology and Correlations**
02:00	**B. Andrei Bernevig** Princeton University **Quantum Geometry in Electron-Phonon Coupling: CDW in Kagome materials and a Famous superconductor**	
02:45	**Valentin Leeb** TU Munich **Quantum Oscillations of the Quasiparticle Lifetime**	
03:15	Coffee Break	
03:45	**Yashar Komijani** University of Cincinnati **Dynamic Mass Generation and Topological Order in Overscreened Kondo Lattices**	
04:15	**Lorenzo Crippa** University of Würzburg **Exceptional Points in strongly correlated materials: spontaneous symmetry breaking and charge response**	

Program

Lecture Hall 2D5

Friday, July 28, 2023



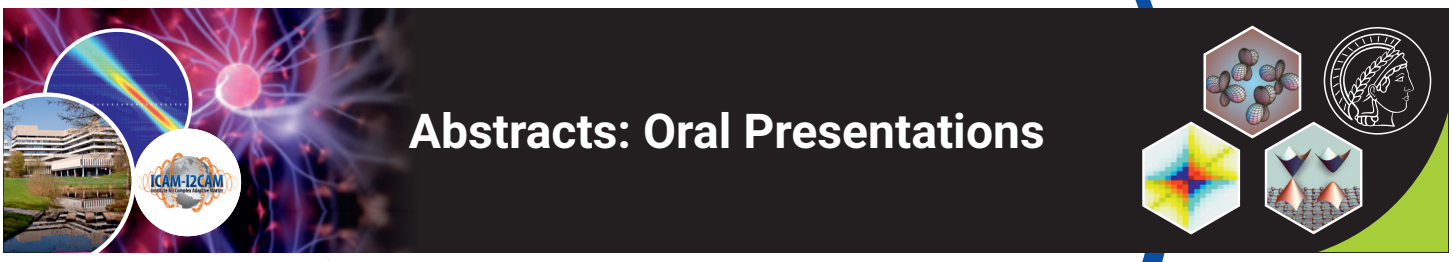
	Session 8	Twistronics
09:00	**Pablo Jarillo-Herrero** MIT **TBA**	
09:45	**Mireia Tolosa Simeón** RUB Bochum **Analog gravity in moiré Dirac materials**	
10:15	Coffee Break	
10:45	**Erez Berg** Weizmann Institute of Science **Novel chiral superconductors**	
11:15	**Anushree Datta** Université de Paris, Laboratoire Materiaux et Phenomenes Quantiques, CNRS and Université Paris-Saclay, CNRS, Laboratoire de Physique des Solides **Heavy quasiparticles and cascades without symmetry breaking in twisted bilayer graphene**	
11:45	Lunch Break	
CEDT PM 01:15	**Discussion**	

ICAM best poster award

There will be an award and a monetary prize of 200€
for the best poster contribution to the CNQM2023 conference.

The decision for the best poster will be taken democratically by the participants of the conference.

To this end, please use the ballots distributed in your conference folder to place your vote by **Wednesday, noon** in the appropriate box.



Abstracts: Oral Presentations

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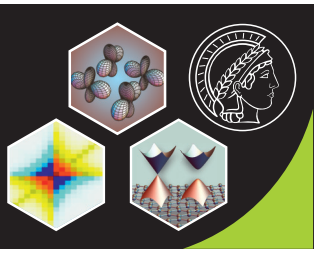
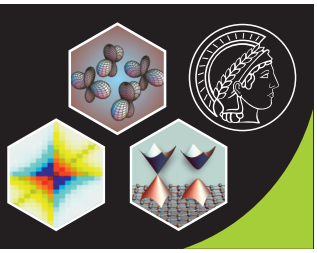


T-1	**Abanin,** Dmitry University of Geneva	Probing non-equilibrium quantum matter with quantum processors
T-2	**Baumberger**, Felix University of Geneva	The fate of quasiparticles beyond the Fermi liquid phase of Sr_2RuO_4
T-3	**Berg**, Erez Weizmann Institute of Science	Novel chiral superconductors
T-4	**Bervenig**, Andrei B. Princeton University	Quantum Geometry in Electron-Phonon Coupling: CDW in Kagome materials and a Famous superconductor
T-5	**Boettcher,** Igor University of Alberta	Topological Hyperbolic Matter on A Circuit Board
T-6	**Bühler-Paschen,** Silke TU Wien	Strange metal behavior in heavy fermion compounds and beyond
T-7	**Capone,** Massimo SISSA	Electron-phonon interaction and strong correlations in multi-orbital systems: Competition or cooperation?
T-8	**Chandra,** Premala Rutgers University	Light-Induced Transitions in Quantum Paraelectrics
T-9	**Chubukov,** Andrey University of Minnesota	Superconductivity near spin and valley orders in Bernal bilayer graphene
T-10	**Coleman,** Piers Rutgers & Royal Holloway	Spin: stem-cell for emergence in quantum materials
T-11	**Crippa,** Lorenzo University of Würzburg	Exceptional Points in strongly correlated materials: spontaneous symmetry breaking and charge response
T-12	**Datta,** Anushree U Paris, CNRS & U Paris-Saclay	Heavy quasiparticles and cascades without symmetry breaking in twisted bilayer graphene
T-13	**de' Medici,** Luca ESPCI Paris	Mott Quantum Critical Points and phase separation at finite doping in Hund metals
T-14	**Georges,** Antoine Collège de France & Flatiron Institute	What Do We Know Today about the 2D Hubbard model?
T-15	**Gull,** Emanuel University of Michigan, Ann Arbor	Let's get real – Adapting the toolkit of many-body theory to realistic materials simulation
T-16	**Jarillo-Herrero,** Pablo MIT	TBA

Abstracts: Oral Presentations



T-17	**Komijani,** Yashar University of Cincinnati	Dynamic Mass Generation and Topological Order in Overscreened Kondo Lattices
T-18	**Le Tacon**, Matthieu IQMT KIT	Novel phenomena and perspectives in 3d- and 5d- transition metal compounds
T-19	**Leeb,** Valentin TU Munich	Quantum Oscillations of the Quasiparticle Lifetime
T-20	**Levchenko,** Alex University of Wisconsin-Madison	Quantum transport from fluctuations near the end point of superconducting dome
T-21	**Moessner,** Roderich MPI-PKS Dresden	Progress in 3d quantum spin liquids
T-22	**Oganesyan,** Vadim CUNY	Quantum annealing with AC field
T-23	**Orth,** Peter P. Saarland University	Nonlinear interrogation of quantum materials: why higher order response tells you more
T-24	**Raghu,** Srinivas Stanford University	Reentrant superconductivity and multiple superconducting phases of UTe_2
T-25	**Reining,** Lucia LSI, CNRS/École Polytechnique	Some thoughts about perturbation theory
T-26	**Reuther,** Johannes FU Berlin	Quantum Effects on Unconventional Pinch Point Singularities
T-27	**Seiler,** Anna University of Göttingen	Correlated phases in the vicinity of tunable van Hove singularities in Bernal bilayer graphene
T-28	**Tolosa-Simeón,** Mireia RUB Bochum	Analog gravity in moiré!Dirac materials
T-29	**Toschi,** Alessandro TU Wien	Characteristic Timescales and Longterm-Memory Effects in Correlated Many-Electron Systems
T-30	**Valentí,** Roser University of Frankfurt	On heavy fermions and doped Mott physics in two-dimensional van der Waals platforms
T-31	**von Delft,** Jan LMU Munich	Fermi surface reconstruction and strange metal behavior at a heavy fermion quantum phase transition
T-32	**Ye**, Mengxing University of Utah	Location and thermal evolution of the pseudogap due to spin fluctuations

Probing non-equilibrium quantum matter with quantum processors

Dmitry Abanin

University of Geneva

The advent of quantum simulators and quantum processors has enabled probing non-equilibrium quantum matter, simultaneously raising fundamental questions about entanglement, complexity and control of many-body states. Theoretical studies revealed new regimes of non-thermalising quantum dynamics (including prethermalization and many-body localization), associated with the emergence of exact or approximate conservation laws. I will discuss the state of the art in studying non-equilibrium matter with quantum processors. As an example, I will describe a recent observation of robust edge modes protected by prethermalization in a chain of up to 46 superconducting qubits. Remarkably, despite external noise, the ″wave function″ of the edge modes can be reconstructed precisely from measuring dynamics of multi-qubit observables, providing an example of an intricate many-body quantity accessible with noisy quantum processors. I will conclude by highlighting recent theoretical developments in classical tensor-network simulation of non-equilibrium phenomena based on the notion of temporal entanglement. I will point out phenomena which are hard to simulate by these and other classical methods, but may soon be within reach of experiments.

The fate of quasiparticles beyond the Fermi liquid phase of Sr_2RuO_4

Felix Baumberger

University of Geneva

A. Hunter, C. Putzke, P. Moll, S. Beck, A. Georges, A. Tamai

Strongly interacting Fermi liquids often turn into bad metals at elevated temperature. Here, we use angle resolved photoemission (ARPES) to study the fate of quasiparticles in the model Fermi liquid Sr_2RuO_4 during this crossover. In contrast to common ARPES folklore, our experiments show that quasiparticles do not disappear via a vanishing residue Z. To the contrary, we find that the residue Z increases with increasing temperature and gradually diminishing coherence. Quasiparticles eventually die not by losing weight but by dissolving via excessive broadening. These findings are in semi-quantitative agreement with dynamical mean field theory calculations.

We further investigate the evolution of the spectral function under uniaxial strain including the regime in which recent transport measurements observed non-Fermi liquid behavior [1]. To this end, we introduce a new method for precision ARPES experiments under continuously varying strain. Our data monitor the tuning the of a van Hove singularity across the chemical potential and show that quasiparticles remain intact in the non-Fermi liquid state at the critical strain. This implies that non-Fermi liquid behavior emerges in Sr_2RuO_4 from subtle changes in the scattering rate rather than from a breakdown of the concept of quasiparticles.

Reference

[1] M. E. Barber, A. S. Gibbs, Y. Maeno, A. P. Mackenzie, and C. W. Hicks, Phys. Rev. Lett. 120, 076602 (2018).

Novel chiral superconductors

Erez Berg

Weizmann Institute of Science

I will discuss new platforms to create and detect chiral (time reversal symmetry breaking) superconductivity. Two systems will be considered: crystalline multi-layer graphene and twist junctions of cuprate superconductors. I will discuss theoretical and experimental considerations in these systems, the prospects for chiral superconductivity, and its possible experimental signatures.

Quantum Geometry in Electron-Phonon Coupling: CDW in Kagome materials and a Famous superconductor

B. Andrei Bernevig

Princeton University

Ab-initio codes are usually very good at giving values for the electron-phonon Macmillan coupling, and, with a bit of extra work, for its momentum resolved counterpart. However, any further information, such as whether there are hidden structures within the electron phonon coupling, and how to control them, is completely lost in the ab-initio process. We here provide an analytic understanding of the constituent parts of the electron phonon coupling for systems with Fermi surfaces, and show that it can be split in two main contributions. Once is “energetic”, and vanished if the band is flat, the other is quantum geometric, and vanishes if the band has no wavefunction variation. We show, using a “Gaussian” approximation that analytic formulas can be obtained for both of these. We also show that in Kagome ScV_6Sn_6 materials, when coupled with a quantum loop calculation, this correctly predicts the phonon softening wave-vector, while in MgB_2, a famous superconductor, 92% of the electron phonon coupling is contained in the quantum geometric part!

Topological Hyperbolic Matter on A Circuit Board

Igor Boettcher

University of Alberta

We introduce the theory and experimental realization of hyperbolic matter, a novel state of matter in curved space that contradicts our Euclidean geometric intuition. It is made of particles moving in the infinite two-dimensional hyperbolic plane. Curvature of space is emulated through a hyperbolic lattice using topolectric circuit networks relying on a newly developed complex-phase circuit element. For a first example, we experimentally realize hyperbolic graphene as an example of topologically nontrivial hyperbolic matter and compare measurements of Dirac particles and Berry curvature to predictions from band theory. As a second example of topological hyperbolic matter, we theoretically discuss Haldane models and Chern insulators on hyperbolic lattices. Our work sets the stage to realize interacting and quantum hyperbolic matter to challenge our established theories of Physics in curved space.

Strange metal behavior in heavy fermion compounds and beyond

Silke Bühler-Paschen

TU Wien

Strange metal behavior – best known as a linear-in-temperature electrical resistivity out of which unconventional superconductivity nucleates – is ubiquitous in many classes of strongly correlated electron systems [1], and has recently also been observed in new flat band platforms. A unified understanding is in high demand. The heavy fermion compound $YbRh_2Si_2$ is a particularly versatile model system for studying this physics. I will present its salient features, including the dynamical scaling of the optical conductivity [2], its superconductivity at ultralow temperatures [3], and its strongly suppressed shot noise [4]. I will also discuss evidence for (some of) these features in other material's classes, the topic of Planckian scattering [5], and how insights gained from all these experimental results may boost the theoretical understanding.

References

[1] S. Paschen and Q. Si, Nat. Rev. Phys. 3, 9 (2021); S. Paschen and Q. Si, Europhys. News 52/4, 30 (2021).
[2] L. Prochaska et al., Science 367, 285 (2020).
[3] D. H. Nguyen et al., Nat. Commun. 12, 4341 (2021).
[4] L. Chen et al., arXiv:2206.00673 (2022); Y. Wang et al., arXiv:2211.11735 (2022).
[5] M. Taupin and S. Paschen, Crystals 12, 251 (2022); X. Li et al., Front. Electron. Mater. 2, 934691 (2023).

Electron-phonon interaction and strong correlations in multi-orbital systems: Competition or cooperation?

Massimo Capone

SISSA

I will discuss the interplay between electron-phonon coupling and electron-electron correlations in multi-orbital Hubbard models. I will show that in a two-orbital Hubbard model coupled with a Jahn-Teller phonon mode, polaronic effects and Mott physics can either compete or coexist according to the ratio between electron-phonon coupling and Hund's exchange [1]. Indeed this follows from the fact that the Jahn-Teller phonon can coexist with the effect of the Hubbard U, while it competes with the Hund's coupling, as discussed some time ago in theories for alkali-doped fullerides [2]. For a half-filled system, this interplay leads to two spectacularly different Mott insulators, a standard high-spin Mott insulator with frozen phonons which is stable when the Hund's coupling prevails, and a low-spin insulator favored by phonons, where the characteristic features of Mott insulators and bipolarons coexist. The two phases are separated by a sharp boundary along which an intermediate solution emerges as a kind of compromise between the two insulators [1]. I will then discuss the stability of this picture with doping, the role of the phonon frequency and the relevance of these results for some materials. I will finally touch on the interplay between electron-phonon coupling and exciton condensation.

This presentation features results obtained in collaboration with A. Scazzola, A. Amaricci, S. Giuli and G. Mazza.

References

[1] A. Scazzola, A. Amaricci and M. Capone, Phys. Rev. B 107, 085131 (2023).
[2] Y. Nomura, S. Sakai, M. Capone and R. Arita, Science Advances 1, e1500568 (2015).

Light-Induced Transitions in Quantum Paraelectrics

Premala Chandra

Rutgers University

Motivated by recent experiments on pump-induced polar ordering in the quantum paraelectric $SrTiO_3$, I will present a study of a driven phonon system close to a second-order polar transition.

Analyzing its classical dynamics, my collaborators and I find that sufficiently strong driving leads to transitions into polar phases whose structures, determined by the light polarization, are not all accessible in equilibrium. In addition, for certain intensity profiles, we demonstrate the possibility of two-step transitions as a function of fluence. For even stronger field intensities, the possibility of period-doubling and chaotic behavior is demonstrated. Finally, I'll present a generalized formalism that allows us to consider quantum corrections to the classical dynamics in a systematic fashion. This leads to the prediction of the shift in the critical pump fluence due to quantum fluctuations with a characteristic dependence on the fluence increase rate that should be observable in experiment.

Reference

[1] Z. Zhuang, A. Chakraborty, PC, P. Coleman and P.A. Volkov, arXiv:2301.06161 (accepted in PRB).

Superconductivity near spin and valley orders in Bernal bilayer graphene

Andrey Chubukov

University of Minnesota

Recent experiments on Bernal bilayer graphene in a finite displacement field discovered a cascade of phase transitions into ordered states at small but finite doping. I will discuss four possible orders, which involve spin and valley degrees of freedom, and analyze superconductivity near each of these ordered states. I will argue that near some of these ordered states, the pairing interaction, mediated by a soft near-critical boson, is attractive, but near other ordered states it remains repulsive. I will discuss how one can still obtain superconductivity, even when boson-mediated pairing interaction is repulsive.

Spin: stem-cell for emergence in quantum materials

Piers Coleman

Center for Materials Theory, Physics and Astronomy, Rutgers University
Department of Physics, Royal Holloway University London

We are rapidly approaching the centenary of quantum mechanics making this a good time to reflect on the past as a springboard for the bold research that the 21st century community of physicists can aspire to. One of the unexpected discoveries of Quantum Mechanics is Spin, a concept introduced in 1925 by a young German at Columbia University, Ralph Kronig. Kronig's bold thesis was strongly refuted by Pauli who claimed "it is indeed very clever but of course has nothing to do with reality", so sadly Kronig chose not to publish. Modern credit for spin goes to Uhlenbeck and Goudsmid. Sometimes it is important to be bold.

In this talk I will discuss spins as the basic quantum building blocks: stem-cells for entanglement and emergence. The incredible aspect of spin are their versatility, for they not only induce magnetism, they can entangle with their surroundings, forming heavy fermion metals and insulators, spin liquids, and heavy fermion superconductors.

I will motivate our discussion with some modern mysteries: the apparent neutral Fermi surface of SmB_6, "Lazarus superconductivity" in UTe_2 and Flux memory in 4Hb-TaS_2. In each of cases, spin transforms the metallic state in surprising ways. I will discuss a possible connection with the CPT model[1]- a solvable model for superconductivity formed between fractionalized spins and electrons.

Work done in collaboration with Alexei M. Tsvelik, Brookhaven National Laboratories, Aaditya Panigrahi, Tamaghna Hazra and Zekun Zhuang at Rutgers University.

Reference

[1] Piers Coleman, Aaditya Panigraphi and Alexei Tsvelik, Phys. Rev. Lett. 129, 177601 (2022).

Exceptional Points in strongly correlated materials: spontaneous symmetry breaking and charge response

Lorenzo Crippa

University of Würzburg

Matthias Reitner, Alessandro Toschi, Giorgio Sangiovanni, Jan Carl Budich

Strongly correlated electronic materials offer one of the standard platforms to detect and classify non-hermitian topological features. These are generally a consequence of the many-body interaction terms, which entail a non-hermitian self-energy and a nontrivial form for two-particle correlation functions. We show how both effects can stabilize a peculiar type of non-hermitian degeneracies known as Exceptional Points. At the 1-particle level, we assess their presence at the onset of spontaneous symmetry-breaking, for systems whose noninteracting Hamiltonian features an unprotected Dirac dispersion. At the 2-particle level, we observe the emergence of Exceptional Points in the eigenvalue spectrum of generalized local charge susceptibilities in the simple Hubbard model, establishing a link between non-hermitian topology and phase instability of the electronic system.

Heavy quasiparticles and cascades without symmetry breaking in twisted bilayer graphene

Anushree Datta

Université de Paris, Laboratoire Materiaux et Phenomenes Quantiques,
CNRS and Université Paris-Saclay, CNRS, Laboratoire de Physique des Solides

Maria Jose Calderon, Alberto Camjayi, Elena Bascones

Among the variety of correlated states exhibited by twisted bilayer graphene (TBG), the cascades in the spectroscopic properties and in the compressibility happen in a larger energy, twist angle and temperature range in comparison to other effects, pointing to a hierarchy of phenomena. Using Dynamical Mean Field Theory + Hartree calculations, we show that the spectral weight reorganization associated to the formation of local moments and heavy quasiparticles, and not a symmetry breaking process, is responsible for the cascade phenomena. Due to the fragile topology of TBG, a strong momentum differentiation is found in the incoherent spectral weight. The phenomena reproduced here include the cascade flow of spectral weight, the oscillations of the remote band energies and the asymmetric jumps of the inverse compressibility.

Mott Quantum Critical Points and phase separation at finite doping in Hund metals

Luca de' Medici

ESPCI Paris

"Hund metals" are multi-orbital paramagnetic metals with sizeable effects due to the intra-atomic exchange energy or Hund's coupling, and are characterised by strong, orbital-selective correlations and large fluctuating local magnetic moments. Their physics is relevant for iron-based superconductors and other materials like transition metal oxides.

A general feature found in models and realistic simulations of these materials, and corroborated by experimental data, is a frontier crossing the doping-interaction strength plane, and originating from the Mott transition point of the half-filled system, across which the aforementioned defining features are strongly enhanced. This frontier is a cross-over at large doping while approaching half-filling it becomes a first-order transition between two metals. It features a phase separation zone ending in a quantum critical point at finite doping. I will show that all this phenomenology is due to the first-order nature of the Mott transition and can be back-tracked to a small energy scale splitting the atomic ground-state multiplet, in this case the Hund's coupling.

What Do We Know Today about the 2D Hubbard model?

Antoine Georges

Collège de France, Paris and CCQ-Flatiron Institute, New York

Simplified as it is, the Hubbard model embodies much of the complexity of the "strong correlation problem" and has established itself as a paradigmatic model in the field, with physical relevance to both cuprates and cold atomic gases in optical lattices. In this talk, I will argue that several key aspects of its physics in two dimensions can now be established beyond doubt, thanks to the development of controlled and accurate computational methods. These methods implement different and complementary points of view on the quantum many-body problem. Along with pushing forward each method, the community has recently embarked into a major effort to combine and critically compare these approaches, and in several instances a consistent picture of the physics has emerged as a result. I will review in this perspective our current understanding of the emergence of a pseudogap in both the weak and strong coupling regimes. I will present recent progress in understanding how the pseudogap phase evolves into an ordered phase at low temperature. The next nearest neighbor hopping t' plays a key role, with low t'/t favoring stripe order and larger t'/t favoring d-wave superconductivity.

I am most grateful for recent collaborations on this topic with Michel Ferrero, Yuan-Yao He, Marcel Klett, Evgeny Kozik, Henri Menke, Olivier Parcollet, Riccardo Rossi, Mathias Scheurer, Fedor Simkovič, Subir Sachdev, Thomas Schäfer, Miles Stoudenmire, André-Marie Tremblay, Alexander Wietek, Nils Wentzell, Steve White, Wei Wu, Bo Xiao and Shiwei Zhang.

Let's get real – Adapting the toolkit of many-body theory to realistic materials simulation

Emanuel Gull

University of Michigan, Ann Arbor

Quantum many-body theories, including diagrammatic perturbation theories and non-perturbative embedding theories, describe the physics of many interacting particles in solids. These theories are typically applied to effective low-energy lattice models, which are designed to capture the essential degrees of freedom of a solid.

This talk will summarize recent progress on solving the many-body problem ab-initio, i.e. without adjustable parameters and without the construction of effective low-energy models, with quantum many-body theories. We will show how algorithmic and computational advances have enabled the adaptation of tools that were previously only available on lattice models to real-materials simulations, and how these simulations avoid several common uncontrolled approximations. A path towards controlled and adaptive many-body simulations is outlined.

Pablo Jarillo-Herrero

MIT

TBA

Dynamic Mass Generation and Topological Order in Overscreened Kondo Lattices

Yashar Komijani

University of Cincinnati

Yang Ge

It has been predicted that multichannel Kondo lattices undergo a symmetry breaking at low temperatures. We use the dynamical large-N technique to ascertain this prediction in a microscopic model on a honeycomb lattice and find out that it is not generally true. Rather, we find a 2+1D conformally invariant fixed point, governed by critical exponents that are found numerically. When we break time-reversal symmetry by adding a Haldane mass to the conduction elections, three phases, separated by continuous transitions, are discernible; one characterized by dynamic mass generation and spontaneous breaking of the channel symmetry, one where topological defects restore channel symmetry but preserve the gap, and one with a Kondo-coupled chiral spin-liquid. We argue that the latter phase, is a fractional Chern insulator with anyonic excitations.

Novel phenomena and perspectives in 3d- and 5d- transition metal compounds

Matthieu Le Tacon

IQMT KIT

Transition metal compounds in which electrons from partially filled d-shells strongly interact with each other keep challenging the standard theory of solids as new, emergent exotic electronic orders are experimentally observed. Despite vastly different macroscopic properties, e.g. high temperature superconductivity (HTS), electronic nematicity or density waves to cite a few, the electronic phases encountered in these quantum materials can be almost degenerate and compete with each other within complex phase diagrams. In this talk I will present a selection of novel results in 3d and 5d transition metal compounds.

I will first discuss the interesting case of the unconventional incommensurate charge-density-waves (I-CDW) in $BaNi2(As_{1-x}P_x)2$ [1], a (non-magnetic) nickel homologue to the Fe-based systems, which exhibits original nematic fluctuations lending support to a type of electronic nematicity, dynamical in nature. Fluctuations between degenerate nematic configurations cause a splitting of phonon lines, without lifting degeneracies nor breaking symmetries, akin to spin liquids in magnetic systems [2].

The second part will be dedicated to a very different system, $SrIrO_3$, a paramagnetic semi-metal. I will show how it is possible to magnetic polarize the conduction electrons [3] of this system and control electrically this magnetization [4], through gating-induced changes of the anomalous Berry curvature of this compound. The large tunability of this system, opens new avenues towards efficient electric-field manipulation of magnetism.

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Quantum Oscillations of the Quasiparticle Lifetime

Valentin Leeb

TU Munich

Nico Huber, Andreas Bauer, Georg Benka, Johannes Knolle,
Christian Pfleiderer, Marc Wilde

Following nearly a century of research, it remains a puzzle that the low-lying excitations of metals are remarkably well explained by effective single-particle theories of non-interacting bands even though mutually interacting electronic states are a property of essentially all materials. This raises the question of direct spectroscopic signatures of phenomena beyond effective single-particle, single-band behaviour. Here we report the identification of quantum oscillations (QOs) of the quasi-particle (QP) lifetime, which defy the standard description in two fundamental aspects. First, the oscillation frequency corresponds to the difference of semi-classical QP orbits of two bands, which are forbidden as half of the trajectory would oppose the Lorentz force. Second, the oscillations persist to much higher temperatures compared to the basis frequencies. The only precondition for their existence is a non-linear coupling of at least two electronic orbits, e.g., due to QP scattering on defects or collective excitations. Such QOs of the QP lifetime are generic for any metal featuring Landau quantization with multiple orbits. We show that the underlying notion of QOs without corresponding Fermi surface cross-sections is in excellent agreement with the three-dimensional topological semimetal CoSi, as well as several other topological semimetals. It offers also an unexpected new perspective on Fe-based superconductors, where a spontaneous emerging QO frequency across the nematic transition has up to now been understood as a Lifshitz transition. We discuss the general relevance of our finding for interpreting QO data in terms of the correct underlying electronic structure.

Huber, Leeb, Bauer, Benka, Knolle, Pfleiderer, Wilde. 2023, [forthcoming]

Leeb, Knolle. 2023, [forthcoming]

Leeb, Knolle. 2023, [forthcoming]

Quantum transport from fluctuations near the end point of superconducting dome

Alex Levchenko

University of Wisconsin-Madison

Motivated by the recent experimental results on the quantum critical transport properties of iron-based superconductors, we investigate the effects of quantum fluctuations on the conductivity of multiband metals near the superconducting quantum critical point (QCP). We consider a minimal model with two nested two-dimensional Fermi surfaces and disorder potentials which include both intra- and inter-band scattering. Inter-band scattering leads to full suppression of the superconducting transition similar to the effect of paramagnetic impurities in an isotropic single-band superconductor. We compute the corrections to conductivity due to superconducting fluctuations and reveal their nonmonotonic temperature dependence. The sign of conductivity correction depends on how the critical point is approached on the phase diagram. We will contrast these results to other known examples of QCP including (i) fluctuations near the upper critical field, (ii) fluctuations in the Pauli-limited regime, and (iii) fluctuations near the depairing type phase transition controlled by the orbital effect of an in-plane magnetic field.

Progress in 3d quantum spin liquids

Roderich Moessner

MPI-PKS Dresden

The study of three-dimensional frustrated magnets has been very challening on account of the lack of controlled methods for treating these correlated quantum many body systems. This talk gives an overview over recent progress, which has seen application of a combination of different approaches - including 3d DMRG, numerical linked cluster expansions, various types of semiclassics and effective field theories - to provide various, and at times quite unexpected, insights into the behaviour of quantum pyrochlore antiferromagnets.

Quantum annealing with AC field

Vadim Oganesyan

City University New York

Quantum annealing is a powerful alternative model for quantum computing, which can succeed in the presence of environmental noise even without error correction. The optimal adiabatic protocol is exponentially fragile to control errors. After reviewing a recently developed method for ameliorating this fragility we demonstrate its application to a specific problem chain freezing in minor embedding.

References

Kapit/Oganesyan 2021
Mossi/Oganesyan/Kapit 2023

Nonlinear interrogation of quantum materials: why higher order response tells you more

Peter P. Orth

Saarland University

The nonlinear response of quantum materials contains a wealth of information that is often hidden in the linear regime. Examples include second-harmonic generation as a sensitive probe of electronic symmetry, and higher-order conductivities that provide insights into the quantum geometry of Bloch states and their Berry curvature distribution. Two-dimensional coherent THz and Raman spectroscopy are two other powerful nonlinear probes of low-energy excitations in quantum materials, which have recently become available in several labs. We review experimental progress and introduce an intuitive theoretical description of these methods in terms of Liouville quantum pathways. We then theoretically show how they can directly probe quasiparticle properties in the Kitaev honeycomb spin liquid and provide direct evidence for the emergence of localized Majorana excitations trapped by vison pairs.

Reentrant superconductivity and multiple superconducting phases of UTe_2

Srinivas Raghu

Stanford University

UTe_2 exhibits a variety of intriguing properties including field-induced reentrance of superconductivity. In the first part of the talk, we will suggest that the reentrance can be accounted for by invoking multiple superconducting phases, for which there is considerable recent experimental evidence. In the second part of the talk, we will describe candidate superconducting order parameters for these various superconducting phases, in the context of a microscopic model having the same symmetries as UTe_2.

Some thoughts about perturbation theory

Lucia Reining

LSI, CNRS/École Polytechnique

One of the most widely used approaches to deal with interacting electrons is many-body perturbation theory. Although it meets its limits when it comes to strong correlation, it performs surprisingly well in other situations. In this talk we will analyze some successes and shortcomings, ranging from models of localized and of delocalized electrons to real materials. We will then advocate new combinations of methods that allow us to overcome the limitations of perturbation theory and to access, with a limited computational cost, physical phenomena that were previously out of reach.

Quantum Effects on Unconventional Pinch Point Singularities

Johannes Reuther

FU Berlin

Fracton phases are a particularly exotic type of quantum spin liquids where the elementary quasiparticles are intrinsically immobile. These phases may be described by unconventional gauge theories known as tensor or multipolar gauge theories, characteristic for so-called type-I or type-II fracton phases, respectively. Both variants have been associated with distinctive singular patterns in the spin structure factor, such as multifold pinch points for type-I and quadratic pinch points for type-II fracton phases. Here, we assess the impact of quantum fluctuations on these patterns by numerically investigating the spin S=1/2 quantum version of a classical spin model on the octahedral lattice featuring exact realizations of multifold and quadratic pinch points, as well as an unusual pinch line singularity. Based on large scale pseudofermion and pseudo-Majorana functional renormalization group calculations, we take the intactness of these spectroscopic signatures as a measure for the stability of the corresponding fracton phases. We find that in all three cases, quantum fluctuations significantly modify the shape of pinch points or lines by smearing them out and shifting signal away from the singularities in contrast to effects of pure thermal fluctuations. This indicates possible fragility of these phases and allows us to identify characteristic fingerprints of their remnants. Besides discussing fraction candidate phases, this talk also briefly introduces the pseudofermion and pseudo-Majorana functional renormalization group methods and demonstrates their strengths in numerically investigating frustrated quantum spin systems.

Correlated phases in the vicinity of tunable van Hove singularities in Bernal bilayer graphene

Anna Seiler

University of Göttingen

Nils Jacobsen, Martin Statz, Fabian Geisenhof, Felix Winterer, Isabell Weimer, Noelia Fernandez, Francesca Falorsi, Kenji Watanabe, Takashi Taniguchi, Tianyi Xu, Zhiyu Dong, Leonid Levitov, Fan Zhang, Thomas Weitz

Diverging density of states can lead to correlated phases in low dimensional systems. This includes the graphene family that hosts electric-field controlled Lifshitz transitions and concomitant van Hove singularities in the density of states. Here, we present the observation of experimental signatures consistent with various interaction-driven phases in hole-doped Bernal bilayer graphene including the fractional metals of Stoner type [1]. More prominently, we have found competing nontrivial insulating and metallic phases that exhibit intriguing temperature dependences and nonlinear I-V characteristics at zero magnetic field [1].
In addition, we report a novel interaction-driven behaviour in the Stoner phases in the electron-doped regime of biased Bernal bilayer graphene. Specifically, we find that the spin- and valley-polarized Stoner phases in this regime exhibit an insulator-like temperature dependence of the conductance. This unexpected behaviour challenges the conventional picture of metallic Stoner magnetism in this system. Furthermore, we find these Stoner phases feature a nonlinear transport behaviour that is sensitive to the onsets of the Stoner orders. These results suggest the emergence of exotic correlated orders beyond Stoner ferromagnetism, such as charge density waves or Wigner crystal states [2].

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Analog gravity in moiré Dirac materials

Mireia Tolosa-Simeón

RUB Bochum

Stefan Floerchinger, Michael Scherer

Condensed matter systems can be used in various scenarios to emulate and study phenomena from a completely different field of physics, for example, elementary particle physics or gravity. Such analog condensed matter models provide a novel perspective to approach questions that are not directly accessible in the original systems as they can potentially be realized experimentally in a well-controlled setup.
In this project, we address the problem of cosmological fermion production in expanding universes using moiré Dirac materials as analog models. Recently, two-dimensional moiré Dirac materials, such as twisted bilayer graphene (TBG), have been established as highly tunable condensed matter platforms allowing us to manipulate electronic band structures and interaction effects in a controlled manner. A remarkable feature of moiré Dirac materials is the presence of fermionic low-energy excitations, described by a quasirelativistic Dirac equation where the velocity of light is replaced by the Fermi velocity. The Fermi velocity can be tuned dynamically over several orders of magnitude leading to a time-dependent metric for the Dirac fermions. In addition, we consider the presence of time-dependent Dirac masses that may originate from symmetry breaking and lead to a finite band gap in the energy dispersion. These ingredients allow us to construct an analog model for the phenomenon of cosmological fermion production in expanding universes, arising due to a time-dependent metric and conformal symmetry breaking.

Characteristic Timescales and Longterm-Memory Effects in Correlated Many-Electron Systems

Alessandro Toschi

TU Wien

Our perception of the natural world is significantly shaped by the properties of the detection process considered. One crucial aspect is the timescale of the probing mechanism: If this is larger than the typical timescales of the phenomenon under investigation, only averaged information will be gained.
I will illustrate the importance of this aspect for the comparison of experimental observations and theoretical calculations of correlated quantum materials, by hands of an ab-initio+dynamical mean-field study [1] of the on-site magnetic fluctuations in several Fe-bases pnictides and chalcogenides. In this respect, I will also highlight the pivotal role played by vertex corrections in driving the slowing-down of the temporal magnetic fluctuations, as it occurs, e.g., in the proximity of Mott-Hubbard/Hund's-Mott metal-to-insulator transitions and of quantum critical points.
Further, I will examine the situations in which the information encoded in the dynamical correlation functions does not completely vanish even in the infinite-time limit, by hands [2] of exact-diagonalization and dynamical mean-field calculations of Hubbard rings and of the Hubbard model, respectively. This analysis will illustrate how to link the asymptotic long-time response of correlated electrons to intrinsic features of the underlying (exact) many-particle energy spectrum, as well as, perspectively, to the entropy of the system under consideration.

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On heavy fermions and doped Mott physics in two-dimensional van der Waals platforms

Roser Valentí

University of Frankfurt

In recent years a plethora of new correlated states have been observed by stacking and twisting two-dimensional van der Waals materials of different kind. Some prominent examples are twisted bilayer graphene, bilayer heterostructures of graphene with the spin-orbit assisted Mott insulator α-$RuCl_3$ -a candidate for Kitaev spin physics-, or bilayer heterostructures of the Mott insulator 1T-TaS_2 with the metal 1H-TaS_2. Unique to these bilayer structures is the emergence of phases such as heavy fermions, quantum spin liquids, correlated metals, or topological superconductivity, not observed in the single layers alone.

In this talk I will discuss the microscopic modelling of such heterostructures by a combination of first-principles calculations, effective-model considerations and many-body techniques, and will present results on the emerging correlated electronic and magnetic properties that we compare with available experiments.

Fermi surface reconstruction and strange metal behavior at a heavy fermion quantum phase transition

Jan von Delft

LMU Munich

We address the sudden reconstruction of the Fermi surface (FS) at the Kondo breakdown (KB) quantum critical point (QCP) in heavy fermion systems. We focus on results on the periodic Anderson model, obtained using a two-site cellular dynamical mean-field theory (CDMFT) approach. By employing the Numerical Renormalization Group to solve the effective impurity model, we are able to dispose of the limitations faced by previous two-site CDMFT studies. At zero temperature, we find a continuous KB-QCP separating two Fermi liquid phases, which differ in their FS volumes. The Fermi liquid scale decreases towards and vanishes at the KB-QCP, giving rise to a non-Fermi liquid quantum critical regime at intermediate temperatures. We discuss several aspects of the KB-QCP and the physics in its vicinity. This includes new results on the FS reconstruction, which is accompanied by the emergence of a Luttinger surface hosting Luttinger quasiparticles; and on the non-Fermi liquid regime, which shows strange metal behavior beyond the marginal Fermi liquid paradigm, including a linear-in-T resistivity and dynamical scaling of the optical conductivity, in good agreement with recent experiments.

Location and thermal evolution of the pseudogap due to spin fluctuations

Mengxing Ye

University of Utah

Andrey Chubukov, Zhentao Wang, Rafael Fernandes

The pseudogap behavior, observed in several classes of materials, most notably high T_c cuprates, remains one of the most debated phenomena in correlated electron systems. In the past few years, there have been significant numerical advances which suggest an important role of spin fluctuations in pseudogap formation at finite temperature. In this talk, I propose a minimal analytical model that can capture the essential features observed numerically and discuss its implications to the phase diagram of high T_c cuprates. I will argue that for proper description of the pseudogap one needs to sum up infinite series of diagrams for both the fermionic Green's function and the SDW order parameter in the SDW state or the magnetic correlation length in the paramagnetic state. As a result, the electrons remain a dynamical memory about the underlying order in a finite temperature range even if the order is already destroyed by thermal fluctuations. This range is split by regions of strong and weak pseudogap behavior. In the first region, the pseudogap energy is weakly temperature dependent, despite that it comes from thermal fluctuations. Generalizations to other systems and the crucial role of vertex corrections will also be discussed.

Abstracts: Poster Presentations

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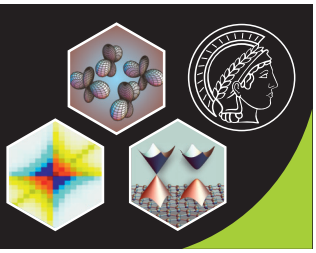
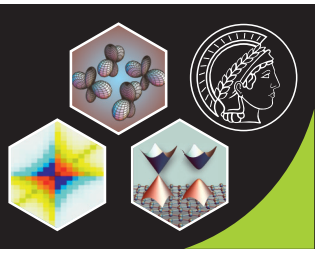


P-1	**Agarwal,** Tarushi IISER Bhopal	Quasi-two-dimensional anisotropic superconductivity in Li intercalated 2H-TaS_2
P-2	**Al-Eryani**, Aiman RUB Bochum	Efficient fRG Flow Equations for Extended Interactions and an Application to the Square and Triangular Lattices
P-3	**Alpin,** Kirill MPI for Solid State Research	Fundamental laws of chiral band crossings: local constraints, global constraints, and topological phase diagrams
P-4	**Amaricci,** Adriano SISSA	Strongly correlated exciton-polarons in twisted homobilayer heterostructures
P-5	**Arouca**, Rodrigo Uppsala University	Exceptionally enhanced topological superconductivity
P-6	**Banerjee,** Sayan University of Innsbruck	Enhanced Superconducting Diode Effect due to coexisting Phases
P-7	**Blason,** Andrea SISSA	Unveiling the Significance of Zeroes of the Green's Function in Strongly Correlated Topological Insulators
P-8	**Blason,** Andrea SISSA	Phonon-mediated local Kekulé distortion turns twisted bilayer graphene into topological Mott insulators and superconductors
P-9	**Bollmann,** Steffen MPI for Solid State Research	Time-reversal invariant topological superconductor in the Coulomb blockade regime
P-10	**Bonetti,** Pietro Maria MPI for Solid State Research	van Hove, Rashba, and Hubbard meet to form first-order and higher-order topological superconductors
P-11	**Borissov,** Anton McMaster University	Field-theoretic functional renormalization group formalism for non-Fermi liquids
P-12	**Braun, Hannes** MPI for Solid State Research	Kohn-Luttinger-like mechanism for CDW
P-13	**Cônsoli,** Pedro Monteiro TU Dresden	Kondo breakdown transitions and phase-separation tendencies in valence-fluctuating heavy-fermion metals
P-14	**da Silva,** João Augusto Sobral University of Innsbruck	Machine Learning Microscopic Form of Nematic Order in twisted double-bilayer graphene
P-15	**de Oliveira,** Mário Malcolms MPI for Solid State Research	Non-local correlations and criticality in the half-filled anisotropic triangular lattice Hubbard model
P-16	**Di Cataldo,** Simone TU Wien	Absence of electron-phonon-mediated superconductivity in hydrogen-intercalated nickelates
P-17	**Fraboulet,** Kilian TU Wien	Single-boson-exchange functional renormalization group and its application to the Hubbard model
P-18	**García-Page,** Ana MPI for Solid State Research	Dragging of Berry curvature in ferromagnetic Weyl semimetals NiMnSb and PtMnSb
P-19	**Gleis,** Andreas LMU Munich	Fermi surface reconstruction and strange metal behavior at a heavy fermion quantum phase transition
P-20	**Grandadam,** Maxence Memorial of Newfoundland	Planckian scaling of the optical conductivity in the 2D Hubbard model
P-21	**Hauck,** Jonas Benedikt RWTH Aachen	Superconductivity in Sr_2RuO_4 revisited from a functional renormalization group perspective
P-22	**Jacobsen,** Nils University of Göttingen	Landau levels marking topological transitions in bilayer graphene
P-23	**Klebl,** Lennart U Hamburg	Spin and Charge Fluctuation Induced Order in ABCB Tetralayer Graphene
P-24	**Kornich,** Viktoriia University of Würzburg	PT-symmetric non-Hermitian superconductivity

Abstracts: Poster Presentations



P-25	**Kourris,** Christos TU Dresden	Kondo screening and coherence on the Kagome lattice: Energy scales of the Kondo effect in the presence of flat bands
P-26	**Krämer,** Marcel TU Wien	Cluster Extension of DMF^{2}RG
P-27	**Krsnik,** Juraj TU Wien	Pi-ton vertex corrections in weakly correlated low-dimensional systems
P-28	**Lotem,** Matan Tel-Aviv University	Kondo Non-Abelian Anyons
P-29	**Marsal,** Quentin Uppsala Universitet	Establishing Coherent Momentum-Space Electronic States in Locally Ordered Materials
P-30	**Mazzilli,** Raffaele MPI for Solid State Research	Electrical transport probes of quantum spin liquids
P-31	**Meixner,** Michael MPI for Solid State Research	The Mott metal-insulator transition in the two-dimensional Hubbard model – a cellular dynamical mean-field study on large clusters
P-32	**Menke,** Henri MPI for Solid State Research	Triangular ad-atom surface lattices as a platform for correlated Hund's physics
P-33	**Moser,** David Jonas TU Dresden	Quasiuniversality from all-in-all-out Weyl quantum criticality in pyrochlore iridates
P-34	**Motruk,** Johannes University of Geneva	Kagome chiral spin liquid in transition metal dichalcogenide moiré bilayers
P-35	**Nambiar,** Gautam University of Maryland	Correlation spectroscopy for correlated materials
P-36	**Nazir,** Arifa IIT Bombay	Study of linear optical properties of T graphene quantum dots
P-37	**Oleś,** Andrzej M. University of Stuttgart	Possible quantum phases in infinite-layer nickelates
P-38	**Paoletti,** Francesca SISSA	Dynamical fluctuations theory of correlated topological insulators
P-39	**Parshukov,** Kirill MPI for Solid State Research	Symmetry-enforced Z_2 topology
P-40	**Parthenios,** Nikolaos MPI for Solid State Research	Twisted bilayer graphene at charge neutrality: competing orders of SU(4) Dirac fermions
P-41	**Patricolo,** Miriam TU Wien	Pseudogap opening in the Hubbard model at strong coupling
P-42	**Pongsangangan,** Kitinan TU Dresden	Thermoelectric transport of charged two-dimensional Dirac systems: the role of plasmons
P-43	**Predin,** Sonja Institute of Physics Belgrade	Dipole representation of half-filled Landau level: quantum Hall and its bilayers
P-44	**Rai,** Gautam University of Hamburg	Electron correlations and spontaneous symmetry-breaking in twisted bilayer graphene
P-45	**Reitner,** Matthias TU Wien	Exceptional susceptibilities: How non-Hermitian topology protects correlation-induced phase instabilities
P-46	**Ritter,** Marc LMU Munich	Quantics Tensor Cross Interpolation for High-Resolution, Parsimonious Representations of Multivariate Functions in Physics and Beyond
P-47	**Rooj,** Suman IISER Bhopal	Antiferromagnetism and spin-orbit interaction driven spin splitting in centrosymmetric hexagonal MnTe
P-48	**Sbierski,** Björn LMU Munich	Magnetism in the two-dimensional dipolar XY model

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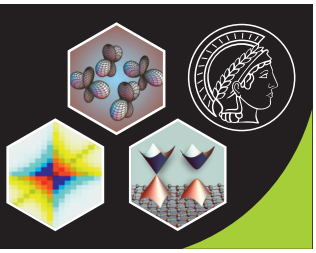

P-49	**Scholle,** Robin MPI for Solid State Research	The zoo of states in the two-dimensional Hubbard model
P-50	**Shreevastava,** Aditi Christ University, Bengaluru	How Cosmic Inflation Solves the Magnetic Monopole Problem?
P-51	**Singhania,** Ayushi IFW Dresden	Disorder effects in the Kitaev-Heisenberg model
P-52	**Starkov,** Grigorii A. RU Bochum	Quantum phase transitions in non-Hermitian PT-symmetric Ising spin chains
P-53	**Sur,** Samudra IISC Bengaluru	Driven Hubbard Model on a Triangular Lattice: Tunable Heisenberg Antiferromagnet with Multiple Ordered and Disordered Phases
P-54	**Tiwari,** Dhruv MPI for Solid State Research	Quantum restoration of Symmetry Protected Topological phases
P-55	**Tscheppe,** Patrick MPI for Solid State Research	Magnetism and metallicity in moiré transition metal dichalcogenides
P-56	**van Loon,** Erik Lund University	Larmor precession in strongly correlated itinerant electron systems
P-57	**Ventura,** Jorge Joe Espinosa Center for Advanced Studies	Synthesis and characterization of carbon quantum dots: comparison with calculation by DFTB+
P-58	**Vilardi,** Demetrio MPI for Solid State Research	Magnetic and pairing fluctuations in the gauge theory of the Pseudogap phase
P-59	**Wang,** Jie Harvard University	Designing Fractionalized Topological Phases by Quantum Geometry
P-60	**Willsher,** Josef TU Munich	Spin-Peierls instability of the U(1) Dirac spin liquid
P-61	**Witt,** Niklas University of Hamburg	Coherence and pairing fluctuations in strongly correlated superconductors
P-62	**Zaera,** Carlos Mejuto SISSA	Multi-orbital phenomenology within the ghost Gutzwiller approximation

Quasi-two-dimensional anisotropic superconductivity in Li intercalated 2H-TaS_2

Tarushi Agarwal

Indian Institute of Science Education and Research Bhopal, India

Anshu Kataria, Chandan Patra, Ravi Prakash Singh, Rajeswari R. Chowdhury

Superconductivity in two-dimensional (2D) materials has sparked great interest due to the emergence of various novel quantum phenomena [1]. Recent experimental studies of 2D superconductivity in anisotropic layered materials propose both conventional and unconventional electron pairing. In this series, layered transition metal dichalcogenides (TMDs) are an intriguing class of materials which are the potential candidates to realise Ising superconductivity, spin-valley coupling, quantum spin hall effect, and non-trivial topologically protected band structure [2]. Chemical doping or intercalation in such materials provides a suitable way to tune the interlayer coupling and thereby tune dimensionality.
Here, I will present my work on the enhanced superconductivity in 2H-TaS_2 by Li intercalation and demonstrate modified superconducting properties of parent compound 2H-TaS_2 after intercalation [3]. The magnetisation, resistivity, and specific heat measurement of single crystals confirmed weakly coupled bulk anisotropic superconductivity having transition temperature at T_c ~ 3.3(1) K. Moreover, the cusp-like feature in angle-dependent magnetotransport measurement and the appearance of Berezinskii-Kosterlitz-Thouless (BKT) phase transition in bulk crystal Li_xTaS_2 suggested the quasi-2D nature of superconductivity. These findings suggest the weakening of interlayer coupling by Li intercalation. There are very few studies in intercalated materials where BKT transition is observed, which makes Li_xTaS_2 a valuable candidate for understanding the superconductivity with BKT mechanism and provide a new insight towards the intercalated materials.

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Efficient fRG Flow Equations for Extended Interactions and an Application to the Square and Triangular Lattices

Aiman Al-Eryani

RUB Bochum

Sarah Heinzelmann, Kilian Fraboulet, Michael Scherer, Sabine Andergassen

The functional renormalisation group has played an important role in providing a tool for unbiased investigation of strongly correlated systems in condensed matter. To aid for a quantitative investigation, a full, yet efficient, momentum [4] and frequency [5] treatment of the vertex and the self-energy is needed. Such methods have been developed in [4] and [5] for local Hubbard interactions, but face challenges upon the introduction of more extended interactions.

We show how the extended interactions can be implemented in a multi-channel partially bosonised fRG flow equations [2, 1] (the so called Single Boson Exchange fRG flow equations), which nonetheless avoids bias resulting from the so called “Fierz ambiguity”. We find that even with extended interactions, the part of the vertex responsible for the multi-boson exchanges is quantitatively negligible - similar to what has been found for local interactions in [3]. This paves the road for the future investigation of extended Hubbard Models (in the form applicable to Moirė materials), and the effect of electron-phonon coupling.

Finally, we present an analysis of the extended Hubbard model on square and triangular geometries at van Hove fillings.

Fundamental laws of chiral band crossings: local constraints, global constraints, and topological phase diagrams

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We derive two fundamental laws of chiral band crossings: (i) a local constraint relating the Chern number to phase jumps of rotation eigenvalues; and (ii) a global constraint determining the number of chiral crossings on rotation axes. Together with the fermion doubling theorem, these laws describe all conditions that a network of chiral band crossing must satisfy. We apply the fundamental laws to prove the existence of enforced double Weyl points, nodal planes, and generic Weyl points, among others. In addition, we show that chiral space-group symmetries can not stabilize nodal lines with finite Chern numbers. Combining the local constraint with explicit low-energy models, we determine the generic topological phase diagrams of all multifold crossings. Remarkably, we find a four-fold crossing with Chern number 5, which exceeds the previously conceived maximum Chern number of 4. We identify materials crystallizing in space group 198, such as B20 materials and BaAsPt, as suitable compounds with this Chern number 5 crossing.

Strongly correlated exciton-polarons in twisted homobilayer heterostructures

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We consider dressing of excitonic properties by strongly correlated electrons in gate-controlled twisted homo-bilayer heterostructures. The combined effect of the moiré potential and the Coulomb interaction supports the formation of different strongly correlated phases depending on the filling, including charge-ordered metals or incompressible insulators at integer occupation. The coupling between excitons and electrons results in a splitting of the excitonic resonance into an attractive and a repulsive polaron peak. Analysing the properties of the exciton-polarons across the different phases of the system, we reveal a discontinuous evolution of the spectrum with the formation of a double-peak structure in the repulsive polaron branch. The double-peak structure emerges for non-integer fillings and it is controlled by the energy separation between the quasiparticle states close to the Fermi level and the high-energy excitations. Our results demonstrate that exciton-polarons carry a clear hallmark of the electronic correlations and, thus, provide a direct signature of the formation of correlation-driven insulators in gate-controlled heterostructures.

Exceptionally enhanced topological superconductivity

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Majorana zero modes (MZMs) emerge as edge states in topological superconductors and are promising for topological quantum computation, but their detection has so far been elusive. Here we show that non-Hermiticity can be used to obtain dramatically more robust MZMs. The enhanced properties appear as a result of an extreme instability of exceptional points to superconductivity, such that even a vanishingly small superconducting order parameter already opens a large energy gap, produces well-localized MZMs, and leads to strong superconducting pair correlations. Our work thus illustrates the large potential of enhancing electronic ordering, here in the form of topological superconductivity, using non-Hermitian exceptional points.

Enhanced Superconducting Diode Effect due to coexisting Phases

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The superconducting diode effect refers to an asymmetry in the critical supercurrent ($\hat{n}$) along opposite directions, ($\hat{n}$)≠Jc($-\hat{n}$). While the basic symmetry requirements for this effect are known, it is, for junction-free systems, difficult to capture within current theoretical models the large current asymmetries ($\hat{n}$)/J($-\hat{n}$) recently observed in experiment. We here propose and develop a theory for an enhancement mechanism of the diode effect arising from spontaneous symmetry breaking. We show---both within a phenomenological and a microscopic theory---that there is a coupling of the supercurrent and the underlying symmetry-breaking order parameter. This coupling can enhance the current asymmetry significantly. Our work might not only provide a possible explanation for recent experiments on trilayer graphene but also pave the way for future realizations of the superconducting diode effect with large current asymmetries.

Unveiling the Significance of Zeroes of the Green's Function in Strongly Correlated Topological Insulators

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The electron Green's function is a powerful tool that describes single-particle excitations in correlated systems, commonly associated with poles in the complex frequency plane. Intriguingly, when strong interactions come into play, the Green's function determinant can also have bands of zeros, corresponding to poles of the self-energy. However, these zeros have long been for long overlooked and considered incidental to the formalism without carrying any physical significance.

In spite of that, these zeroes do possess a topological character. Indeed, we show that when the thermal Green's function is invertible, nor poles neither zeros at zero Matsubara frequency, thus representing a bona fide insulator, the two-dimensional quantized Hall conductance, which is a topological invariant, is equally contributed by bands of poles and bands of zeros. This result is exact and fully non-perturbative, insofar the Luttinger-Ward functional of the Green's functions can be defined non-perturbatively, as rigorously shown, whose first functional derivative yields the self-energy, and second functional derivative the irreducible scattering vertex. This result, which we believe is readily extendable in higher dimensions and for other topological invariants, brings to light the importance of the Green's functions band of zeros, especially in Mott topological insulators.

Phonon-mediated local Kekulé distortion turns twisted bilayer graphene into topological Mott insulators and superconductors

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Magic-angle twisted bilayer graphene exhibits diverse, fascinating phases when the four flat bands around the charge neutrality point are partially filled. These phases include magnetic Chern insulators with predominantly orbital magnetization and adjacent superconducting regions. Recent scanning tunneling microscopy (STM) measurements on low strain samples have provided evidence of a local Kekulé pattern at the graphene scale in the half-filling insulating state.

The emergence of these intriguing phases can be attributed to the cooperative effects of Coulomb repulsion and electron coupling to a twofold optical mode associated with Kekulé distortions and localized in the small AA-stacked regions of the moiré supercells. At any integer filling of the flat bands, a static distortion stabilizes valence-bond insulators with non-zero Chern numbers away from charge neutrality. Furthermore, a dynamic distortion arising from resonating lattice vibrations gives rise to resonating-valence-bond topological insulators, featuring chiral d-wave pairs with Chern numbers equal to the angular momentum. This picture naturally leads to superconductivity upon doping away from integer fillings. The compelling agreement between this phonon-mediated local Kekulé distortion scenario and experimental observations underscores the pivotal role of phonons in driving the ground state properties of twisted bilayer graphene.

Time-reversal invariant topological superconductor in the Coulomb blockade regime

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Jukka Väyrynen, Elio J. König

Floating topological superconductors coupled to conduction electrons can realize unconventional O(N), Sp(2N), or multi-channel Kondo effects. Here, we introduce a new topological superconducting mesoscopic device, a time-reversal invariant version of the Majorana Cooper pair box in the Coulomb blockade regime. In this setup of Cartan-Altland-Zirnbauer class DIII, spinful Majorana zero modes appear at the edges of a topological triplet superconductor with fluctuating Cooper pair spin and charge. We study the Kondo effect in the limit of dominating charging energy and in the limit of both small and large spin fluctuations. Beyond its value in the context of exotic mesoscopic Kondo effects, our study sheds light on the intricate interplay of band topology and strong quantum fluctuations of non-Abelian order parameter fields.

van Hove, Rashba, and Hubbard meet to form first-order and higher-order topological superconductors

Pietro Maria Bonetti

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Debmalya Chakraborty, Andreas Schnyder, Xianxin Wu

We investigate topological superconductivity in the Rashba-Hubbard model, describing heavy-atom superlattice and van der Waals materials with broken inversion. We focus in particular on fillings close to the van Hove singularities, where a large density of states enhances the superconducting transition temperature. To determine the topology of the superconducting gaps and to analyze the stability of their surface states in the presence of disorder and residual interactions, we develop an fRG+MFT approach, which combines the unbiased functional renormalization group (fRG) with a real-space mean-field theory (MFT). Our approach uncovers a cascade of topological superconducting states, including $A1$ and $B1$ pairings, whose wave functions are of dominant p- and d-wave character, respectively, as well as a time-reversal breaking $A1+iB1$ pairing. While the $A1$ and $B1$ states have first order topology with helical and flat-band Majorana states, respectively, the $A1+iB1$ pairing exhibits second-order topology with Majorana corner modes.

Field-theoretic functional renormalization group formalism for non-Fermi liquids

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To capture the universal low-energy physics of metals within effective field theories, one has to generalize the usual notion of scale invariance and renormalizable field theory due to the presence of intrinsic scales (Fermi momenta). In this work, we develop a field-theoretic functional renormalization group formalism for full low-energy effective field theories of non-Fermi liquids that include all gapless modes around the Fermi surface. The formalism is applied to the non-Fermi liquid that arises at the antiferromagnetic quantum critical point in two space dimensions. In the space of coupling functions, an interacting fixed point arises at a point with momentum-independent couplings and vanishing nesting angle. In theories deformed with non-zero nesting angles, coupling functions acquire universal momentum profiles controlled by the bare nesting angles at low energies before flowing to superconducting states in the low-energy limit. The superconducting instability is unavoidable because lukewarm electrons that are coherent enough to be susceptible to pairing end up being subject to a renormalized attractive interaction with its minimum strength set by the nesting angle irrespective of the bare four-fermion coupling. Despite the inevitable superconducting instability, theories with small bare nesting angles and bare four-fermion couplings that are repulsive or weakly attractive must pass through the region with slow RG flow due to the proximity to the non-Fermi liquid fixed point. The bottleneck region controls the scaling behaviours of the normal state and the quasi-universal pathway from the non-Fermi liquid to superconductivity. In the limit that the nesting angle is small, the non-Fermi liquid scaling dictates the physics over a large window of energy scale above the superconducting transition temperature.

Kohn-Luttinger-like mechanism for CDW

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Laura Classen

We propose a Kohn-Luttinger-like mechanism for charge density waves in correlated electron systems with higher symmetries SU(N).The mechanism is responsible for an instability with finite transfer momentum in the particle-hole direct channel which emerges due to the feedback from the particle-hole crossed channel. Like in the original Kohn-Luttinger mechanism, the separation of momentum channels in different lattice harmonics is the key for getting attractive components out of an initially repulsive interaction. Using the truncated unity fRG we find evidence that this very mechanism produces an imaginary charge density wave in an SU(4)-invariant triangular lattice Hubbard model around Van Hove filling.

Kondo breakdown transitions and phase-separation tendencies in valence-fluctuating heavy-fermion metals

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The breakdown of the lattice Kondo effect in local-moment metals can lead to non-trivial forms of quantum criticality and a variety of non-Fermi-liquid phases. Given indications that Kondo-breakdown transitions involve criticality not only in the spin but also in the charge sector, we investigate the interplay of Kondo breakdown and strong valence fluctuations in generalized Anderson lattice models. We employ a parton mean-field theory to describe the transitions between deconfined fractionalized Fermi liquids and various confined phases. We find that rapid valence changes near Kondo breakdown can render the quantum transition first order. This leads to phase-separation tendencies which, upon inclusion of longer-range Coulomb interactions, will produce intrinsically inhomogeneous states near Kondo-breakdown transitions. We connect our findings to unsolved aspects of experimental data.

Machine Learning Microscopic Form of Nematic Order in twisted double-bilayer graphene

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Modern scanning probe techniques, like scanning tunneling microscopy (STM), provide access to a large amount of data encoding the underlying physics of quantum matter. In this work, we analyze how convolutional neural networks (CNN) can be employed to learn effective theoretical models from STM data on correlated moiré superlattices. These engineered systems are particularly well suited for this task as their enhanced lattice constant provides unprecedented access to intra-unit-cell physics and their tunability allows for high-dimensional data sets within a single sample. Using electronic nematic order in twisted double-bilayer graphene (TDBG) as an example, we show that including correlations between the local density of states (LDOS) at different energies allows CNNs not only to learn the microscopic nematic order parameter, but also to distinguish it from heterostrain. These results demonstrate that neural networks constitute a powerful methodology for investigating the microscopic details of correlated phenomena in moiré systems and beyond.

Non-local correlations and criticality in the half-filled anisotropic triangular lattice Hubbard model

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We investigate the role of non-local electronic correlations at finite temperatures in the half-filled anisotropic triangular lattice Hubbard model using the dynamical vertex approximation (DΓA), a diagrammatic extension [1] of the dynamical mean-field theory (DMFT). We analyze the impact of (quantum) phase transitions on finite temperature properties at the one- and two-particle level. We also discuss the implications of the absence of magnetic ordering at finite temperatures due to the fulfilment of the Mermin-Wagner theorem.

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Absence of electron-phonon-mediated superconductivity in hydrogen-intercalated nickelates

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The recently discovered nickelate superconductors represent one of the raising hot topic in the research area of strongly-correlated superconductors. A recent experiment [X. Ding et al., Nature 615, 50 (2023)] indicates that superconductivity in nickelates is restricted to a narrow window of hydrogen concentration: $0.22 < x < 0.28$ in $Nd_{0.8}Sr_{0.2}NiO_2H_x$. This reported necessity of hydrogen suggests that it may play a crucial role for superconductivity, as it does in the vast field of hydride superconductors, by boosting the electron-phonon coupling and hence a source of conventional superconducting pairing. Using density-functional theory and its extensions, we explore the effect of topotactic hydrogen on the electronic structure and phonon-mediated superconductivity in nickelate superconductors. Our calculations show that the electron-phonon coupling in hydrogen-intercalated nickelates is not strong enough to drive the electron pairing, and thus cannot explain the reported superconductivity.

Single-boson-exchange functional renormalization group and its application to the Hubbard model

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The functional renormalization group (fRG) is already established as a powerful tool to study many-electron systems. Furthermore, the single-boson-exchange (SBE) decomposition of two-particle vertices, which consists in a bosonization in all channels, has proven to be a particularly efficient parametrization of fermionic problems, both within parquet- and fRG-based approaches. We discuss here the formulation of the fRG based on the SBE decomposition, coined as SBE fRG, and its application to the two-dimensional Hubbard model. We stress particularly how and why the SBE formalism allows us to reach an efficient description of the problem at reasonable numerical costs. An important outlook of such a study is the inclusion of multiloop corrections, that we will briefly discuss as well.

Dragging of Berry curvature in ferromagnetic Weyl semimetals NiMnSb and PtMnSb

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The Anomalous Hall effect (AHE) is a transport phenomenon in ferromagnets, which exhibit currents even in the absence of a magnetic field. Their inner magnetization breaks Time Reversal Symmetry, allowing the Berry Curvature (BC) to be finite. As a result, topological features close to the Fermi energy have a deep impact in the transport properties, leading to huge Anomalous Hall Conductivities (AHC). This has been a well-stablished paradigm for the last years for the linear AHC. However, some recent experimental results might be pointing to something beyond it.

Fermi surface reconstruction and strange metal behavior at a heavy fermion quantum phase transition

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We address the sudden reconstruction of the Fermi surface (FS) at the Kondo breakdown (KB) quantum critical point (QCP) in heavy fermion systems. We focus on results on the periodic Anderson model, obtained using a two-site cellular dynamical mean-field theory (CDMFT) approach. By employing the Numerical Renormalization Group to solve the effective impurity model, we are able to dispose of the limitations faced by previous two-site CDMFT studies. At zero temperature, we find a continuous KB-QCP separating two Fermi liquid phases, which differ in their FS volumes. The Fermi liquid scale decreases towards and vanishes at the KB-QCP, giving rise to a non-Fermi liquid quantum critical regime at intermediate temperatures.

We discuss several aspects of the KB-QCP and the physics in its vicinity. This includes new results on the FS reconstruction, which is accompanied by the emergence of a Luttinger surface hosting Luttinger quasiparticles and on the non-Fermi liquid regime, which shows strange metal behavior beyond the marginal Fermi liquid paradigm, including a linear-in-T resistivity and dynamical scaling of the optical conductivity, in good agreement with recent experiments.

Planckian scaling of the optical conductivity in the 2D Hubbard model

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James LeBlanc

The optical conductivity of systems with strong interactions is one of the most studied quantities experimentally, yet its computation from microscopic models remains challenging. In the context of linear response theory and of the Kubo formula for conductivity, this difficulty is embedded in the momentum and energy dependence of the electron self-energy and of the vertex corrections. One popular approach to treat the former is the use of Dynamical Mean-Field Theory (DMFT), the resulting self-energy however is purely local and the associated vertex correction in the conductivity vanishes. Multiple studies have shown that these vertex corrections are extremely relevant [1] in the two-dimensional Hubbard model, especially close to half-filling [2].

In this work, we present a study of the optical conductivity using Algorithmic Matsubara Integration [3] (AMI) which allows for the evaluation of diagrammatic series up to a fixed order. Contrary to other popular numerical techniques based on diagrammatic expansions such as Diagrammatic Quantum Monte-Carlo, the evaluation of the Matsubara summations is done analytically for every diagram. In particular, this allows us to evaluate the series directly on the real frequency axis, without relying on analytic continuation tools such as maximum entropy or Pade approximant. The resulting optical conductivity is obtained at different temperatures at the leading order and its non-trivial frequency dependence is analyzed through the lens of an extended Drude model by introducing a frequency-dependent scattering time and mass enhancement. We recover the linear temperature dependence of the dc resistivity that has been observed in previous work [4,5]. Additionally, we show that the optical conductivity presents a regime of power-law scaling at intermediate frequencies. This scaling satisfies a "Planckian"-like behaviour similar to the one expected in the strange metal regime of non-fermi liquids [6] and reported in experiments [7]. We extend the analysis to include vertex corrections as well as study the effect of doping away from the half-filled case.

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Superconductivity in Sr_2RuO_4 revisited from a functional renormalization group perspective

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The superconducting symmetry of Sr_2RuO_4 is one of the long standing problems of material science. Even though the normal state of the material can be well described in terms of density functional theory plus dynamical mean-field theory calculations, the character of the superconducting state remains elusive. In this paper we investigate the behavior of the superconducting order parameter under strain along the [1 0 0] direction, using density functional theory plus functional renormalization group simulations for a 2D model. We find a dominant $d_{x^2-y^2}$ superconductor in the d_{xy}-orbital with no closely related additional order parameter component. We can reproduce the experimentally observed change of Tc under strain within this framework and propose a simple mechanism explaining the observed behavior. By comparing theory and experiment, we can construct further constrains for a possible degenerate partner of the $d_{x^2-y^2}$ superconducting state.

Landau levels marking topological transitions in bilayer graphene

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We investigate Landau levels in an electron band that exhibits a topological Lifshitz transition. We focus on Bernal-stacked bilayer graphene, a system that has drawn a lot of attention recently. A dual gated experimental setup allows to tune the out-of-plane displacement field and the charge carrier density independently, giving insights in exotic correlation effects [1]. Depending on the charge carrier density its Fermi surface changes its topology, that is, four disconnected pockets merge together to form one connected Fermi sea [2].

This topological transition results in a complex series of Landau levels which are not valley-symmetric and, as a result, change their order and degeneracy when the magnetic field is varied. These effects are added to the degeneracies that are already present due to valley and spin degrees of freedom. By virtue of numerical diagonalization methods based on a realistic tight binding model, we extract this Landau level sequence and directly relate it to transport measurements. Our model allows us to access the range of parameters of interest where the topological Lifshitz transition can occur.

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Spin and Charge Fluctuation Induced Order in ABCB Tetralayer Graphene

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Motivated by the recent experimental realization of ABCB stacked quadlayer graphene [Wirth et al., ACS Nano 16, 16617 (2022)], we study correlated phenomena in moiré-less graphene tetralayers for realistic interaction profiles using an orbital resolved, weak coupling random phase approximation approach. We demonstrate that spin fluctuations originating from local interactions are crucial close to the van-Hove singularities on the electron- and hole-doped side promoting orbitally selective ferrimagnetic spin alignments. Magnetic fluctuations around these correlated states enhance unconventional spin-triplet, valley-singlet superconductivity with f-wave symmetry due to intervalley scattering. Charge fluctuations arising from long-ranged Coulomb interactions promote doubly degenerate p-wave superconductivity close to the van Hove singularities. At the conduction band edge of ABCB graphene, we find that both spin and charge fluctuations drive f-wave superconductivity. Our analysis suggests strong competition between superconducting states emerging from long- and short-ranged Coulomb interactions and thus stresses the importance of microscopically derived interaction profiles to make reliable predictions for the origin of superconductivity in graphene based (moiré-less) heterostructures.

PT-symmetric non-Hermitian superconductivity

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PT-symmetric structures have received particular interest due to their multiple applications in optics and synthetic materials. PT-symmetric superconductivity is a rather new, developing field. Here, I will show theoretically how such superconductor can be obtained due to spatio-temporal modulations of a material, that can lead to asymmetric electron-electron interaction. I will discuss Andreev bound states that appear in the junction with two conventional superconductors only at discrete values of phases of conventional superconductors. I will show, how Andreev scattering in a junction of PT-symmetric non-Hermitian superconductor with normal metal can be a check for validity of non-Hermitian formalism.

Kondo screening and coherence on the Kagome lattice: Energy scales of the Kondo effect in the presence of flat bands

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The formation of a heavy Fermi liquid in metals with local moments is characterized by multiple energy and temperature scales, most prominently the Kondo temperature and the coherence temperature, characterizing the onset of Kondo screening and the emergence of Fermi-liquid coherence, respectively. In the standard setting of a wide conduction band, both scales depend exponentially on the Kondo coupling. Here we discuss how the presence of a flat, i.e., dispersionless, conduction band modifies this situation. The Kagome Kondo-lattice model, due to its rich band structure, leads to a plethora of non-conventional Kondo behaviour emerging at different fillings. We utilize a parton mean-field approach to determine both the Kondo temperature and the coherence temperature as function of the conduction-band filling nc, both numerically and analytically. For nc values corresponding to the flat conduction band, we show that the exponential is replaced by linear and quadratic dependences for the Kondo and coherence temperature respectively, while a cubic power law emerges in the coherence temperature at nc corresponding to the band edge between the flat and dispersive bands.

Cluster Extension of DMF^{2}RG

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The DMF^{2}RG has been introduced to overcome the weak-coupling limitation of the fRG. This approach builds on the idea to exploit the dynamical mean-field theory (DMFT) as starting point for the flow, thus capturing local non-perturbative correlations via DMFT together with perturbative nonlocal correlations generated during the flow. We discuss how the DMF^{2}RG can be extended to describe nonperturbative nonlocal correlations, by using cluster DMFT or cellular DMFT as starting point of the flow.

Pi-ton vertex corrections in weakly correlated low-dimensional systems

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The optical conductivity in a wide variety of correlated models has been shown to be dominated by pi-ton vertex corrections, which describe the coupling of light with antiferromagnetic or charge density wave fluctuations with a wave vector close to q = (pi, pi, ...) [1]. While the analysis [2] of the pi-ton vertex corrections in two-dimensional (2D) weakly correlated systems show that they generally lead to a temperature-dependent broadening/sharpening of a Drude peak, it has been pointed out in [3] and [4] that in one-dimensional (1D) systems an additional pi-ton peak between the Drude and the high-frequency features may appear. However, in the latter work, analytical continuation was necessary in the final step to obtain the real frequency optical spectra, which makes the analysis of fine spectral features a bit cumbersome. Therefore, here we semianalytically study the pi-tons on a level of a random phase approximation ladder in the transversal particle-hole channel, analogous to the approach in [2], to differentiate and identify their characteristic features in weakly correlated 1D and 2D systems. Our results show that in 1D systems, the pi-ton vertex corrections are indeed way stronger than in 2D systems, leading to features beyond the simple renormalization of the Drude peak.

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Kondo Non-Abelian Anyons

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Non-Abelian anyons typically emerge in gapped topological models, and give rise to a fusion space which scales with a fractional quantum dimension to the power of the number of anyons. It is also well established that a single spin-1/2 impurity coupled to k multiple fermionic channels results in a fractional entropy equal to the quantum dimension of a single (2) anyon. Generalizing this to multiple impurities, thus giving rise to an anyonic fusion space in a gapless electronic model, has long been a challenge. Employing Wilson's numerical renormalization group (NRG) we demonstrate that by utilizing chiral channels (e.g., integer quantum Hall edge states), this is possible. First we introduce a chiral generalization of NRG [PRB 107, 155417], and prove that due to chirality, locally the physics is indifferent to the inter-impurity distance. Armed with this insight, we map a multi-impurity chiral model to an effective single-impurity model [PRL 129, 227703], amenable to standard NRG, and demonstrate the emergence of an anyon at each impurity. We further demonstrate that the anyonic fusion space can be manipulated, i.e., braided, by measurements of inter-impurity spin correlations. Impressive recent advances on realizing multichannel Kondo systems with chiral edges may thus bring non-Abelian anyons into existence in the near future.

Establishing Coherent Momentum-Space Electronic States in Locally Ordered Materials

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Many current and future quantum technologies rely on amorphous materials, where translational symmetry is broken, but short-range order with well-defined structural length scales persists [1]. This brings forward the fundamental question whether long-range order is a necessary condition to establish coherence and structured momentum-dependent electronic state, and how to characterize it in the presence of short-range order. By using angle resolved photoemission spectroscopy together with our simulations using amorphous Hamiltonians to directly access the electronic states in a momentum resolved manner, we reveal that, even in the absence of long-range order, a well-defined real-space length scale is sufficient to produce dispersive band structures. Moreover, we observe for the first time a repeated Fermi surface structure of duplicated annuli, reminiscent of Brillouin zone-like repetitions.

These results [2], not only lead the way to a new understanding of electronic coherence in solids, but also open the way to the realization of novel momentum-dependent quantum phenomena such as momentum pairing and spin-orbit coupling, in a much broader class of materials than the currently studied ones, lacking long range crystalline translational symmetry.

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Electrical transport probes of quantum spin liquids

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Quantum spin liquids are an exotic phase of matter characterized by the presence of fractionalized excitations(spinons) and emergent gauge fields. One of the difficulties in probing experimentally a QSL phase comes from the fact that the spinons do not carry an electric charge, ruling out the possibility of using conventional electrical probes. Going beyond conventional transport, we propose two setups of electric probes to characterize a QSL phase. First, we analyze a setup in which a QSL layer is interposed between two metallic layers. In this setup, we apply a current in the first metallic layer and measure the induced voltage on the second one. The momentum transfer is affected by the non-trivial behavior of momentum-carrying spinons and results in a response that will potentially be helpful for the future characterization of candidate QSL materials.

The second probe we propose is an STM experiment on a Kondo lattice in which the local moments have non-trivial dynamics (hence forming a QSL phase). We provide the STM response in each of the phase configurations of this system allowing also for the possibility for the conduction electrons and for the spinons to form a superconducting phase. This last setup might find a concrete realization in materials such as TaS_2, $TaSe_2$, and $NbSe_2$ in the 1T, 2H, and in the 4Hb crystallographic phases.

The Mott metal-insulator transition in the two-dimensional Hubbard model – a cellular dynamical mean-field study on large clusters

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We study the half-filled two-dimensional Hubbard model on a square lattice in cellular dynamical mean-field theory (CDMFT), a real-space cluster extension [1] of the dynamical mean-field theory. By increasing the number of cluster sites up to 6x6 we observe a progressive reduction of the onset interaction U of a metal-insulator crossover. In particular, in the case of 4x4 sites, we observe a site- dependent U, which is lower at the center sites than at the corner sites. In addition to this real-space analysis we investigate different periodization schemes for the one-particle spectral function in the half-filled and doped case.

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Triangular ad-atom surface lattices as a platform for correlated Hund's physics

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In the triangular lattice Hubbard model, the interplay of strong correlations and geometrical frustration gives rise to a variety of emergent phenomena. At intermediate coupling a metal-insulator transition is observed and spin liquid physics have been proposed, whereas at strong coupling a magnetic insulator is found. Triangular lattice structures can be realized in a variety of materials, such as layered transition metal dichalcogenides, organic salts of the κ-ET family, or X:Si(111) ad- atom systems (X = Pb, Sn, C), where various kinds of correlated phenomena have been observed. In this work we propose X:SiC(0001) ad-atom systems (X = Cr, V, Ti) as a new platform to control and probe two-band physics in the triangular lattice Hubbard model. In particular we expect Hund's coupling to play a major role in the physics of V:SiC(0001). We use first-principles density functional theory calculations in conjunction with the constrained random phase approximation to derive a material-realistic model for the electronic structure. Using dynamical mean-field theory we explore the phase diagram as a function of ad-atom species and temperature.

Quasiuniversality from all-in-all-out Weyl quantum criticality in pyrochlore iridates

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We identify an exotic quasiuniversal behavior near the all-in-all-out Weyl quantum critical point in three-dimensional Luttinger semimetals, such as the pyrochlore iridates $R_2Ir_2O_7$, with R a rare-earth element. The quasiuniversal behavior is characterized by power laws with exponents that vary slowly over several orders of magnitude in energy or length. However, in contrast to the quasiuniversality discussed in the context of deconfined criticality, the present case is characterized by a genuinely-universal ultra-low-temperature behavior. In this limit, the pertinent critical exponents can be computed exactly within a renormalization group analysis. Experimental implications for the pyrochlore iridates are outlined.

Kagome chiral spin liquid in transition metal dichalcogenide moiré bilayers

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At n=3/4 filling of the moiré flat band, transition metal dichalcogenide moiré bilayers will develop kagome charge order. We derive an effective spin model for the resulting localized spins and find that its further neighbor spin interactions can be much less suppressed than the corresponding electron hopping strength. Using density matrix renormalization group simulations, we study its phase diagram and, for realistic model parameters relevant for WSe_2/WS_2, we show that this material can realize the exotic chiral spin liquid phase and the highly debated kagome spin liquid. Our work thus demonstrates that the frustration and strong interactions present in TMD heterobilayers provide an exciting platform to study spin liquid physics.

Correlation spectroscopy for correlated materials

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Spectroscopy constitutes an important family of experiments to study condensed matter systems, where one obtains information about a material by shining photons at it and measuring the intensity of the scattered photons. However the modern AMO toolbox allows one to measure not just the intensity, but also other observables such as second order coherence (g(2)) and homodyne signal. What these measurements reveal about the condensed matter system being studied is a nontrivial question. In this work, we develop a framework to determine which correlation functions of the material are encoded in such measurements. We specialize to the Hubbard model at half-filling and find that a slew of dynamical spin-spin and spin-charge correlations can be measured this way. Our framework can be used straightforwardly by an experimentalist to determine the corresponding correlations for their matter system, provided they know its microscopic light-matter interaction Hamiltonian.

Study of linear optical properties of T graphene quantum dots

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In this paper, we present computations of the optical absorption spectra of T graphene quantum dots (TGQD) employing a π-electron method and long-range Coulomb interactions within the Pariser-Parr-Pople (PPP) model Hamiltonian [1][2]. The Configuration-Interaction (CI)[3][4] approach is used at various levels to incorporate electron-correlation effects on the ground and excited states. The method is thoroughly benchmarked by calculating the linear optical absorption spectra of several types of TGQDs. The outcomes are in good agreement with those attained by First-principles calculations. We investigated the influence of TGQDs' size and shape on their optical properties. The symmetry of the TGQDs is explored to identify allowed dipole transitions. It was revealed that HOMO to LUMO transition is dipole forbidden, suggesting that the optical and electronic band gaps of these TGQDs are different. Absorption maxima of these TGQDs are observed in UV to visible regions of light. Overall, our theoretical approach describes the linear optical characteristics of T-graphene quantum dots, which may offer helpful information for experimental characterization of these materials.

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Possible quantum phases in infinite-layer nickelates

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Superconductivity found in doped $NdNiO_2$ is puzzling as two local symmetries of doped NiO_2 layers compete, with presumably far-reaching implications for the involved superconductivity mechanism. With increasing value of the charge-transfer energy we observe upon hole doping the expected crossover from the cuprate regime dominated by Zhang-Rice singlets to the local triplet regime for doped nickelates. A second Ni(3d) orbital can easily become relevant, with either the xy or the $3z^2-r^2$ orbitals contributing together with the x^2-y^2 orbital to the formation of local triplet states. The phase transition to triplet states depends on the interorbital Coulomb repulsion Udp (acting between Ni and O) favors on-site triplets implies that correlation effects beyond purely on-site interactions should be taken into account when obtaining effective two-band models. With increasing value of the charge-transfer energy, we observe the expected crossover from a singlet to a local triplet regime upon hole doping. The screened interactions for the s band suggest the importance of rare-earth atoms in superconducting nickelates. Next, starting from an effective two-dimensional two-band model for infinite-layer nickelates, consisting of bands obtained from d- and s-like orbitals, we investigate to which extent it can be mapped onto a single-band Hubbard model. We identify screening of the more itinerant s-like band as an important driver [2]. In the absence of screening one strongly correlated band gives an antiferromagnetic ground state. For weak screening, the strong correlations push electrons out of the s band so that the undoped nickelate remains a Mott insulator with a single half-filled x^2-y^2 band and two Hubbard sub-bands [3]. This regime differs markedly from the observations in high-T_c cuprates – then pairing with s-wave symmetry would rather be expected in the superconducting state. In contrast, for strong screening, the s and x^2-y^2 bands are both partly filled and couple only weakly, so that one approximately finds a self-doped d band, as well as tendencies toward d-wave pairing. Particularly, in the regime of strong screening mapping to a one-band model gives significant spectral weight transfers when a second s band is also partly filled. We thus find that both one-band physics and a Kondo-lattice-like regime emerge from the same two-orbital model, depending on the strength of electronic correlations and on the size of the s-band pocket.

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Dynamical fluctuations theory of correlated topological insulators

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Topological quantum phase transitions (TQPTs) describe a change in the electronic band structure (as in topological insulators), or in the shape of the Fermi surface (Lifshitz). It is commonly assumed that TQPTs don't follow the conventional Ginzburg-Landau scheme, nonetheless this is not at odds with the possibility of a description based on the relevant observables of the system, beside the change in the global topological invariants. Here, we introduce a functional integral fluctuations method to calculate the free energy for a paradigmatic model of the interacting quantum spin Hall insulators, where the strong electronic interactions are expected to drive a first order jump in the orbital polarization at the TQPT. In particular, we demonstrate that the mean-field approximation fails to capture this change of character, therefore emphasizing the fundamental role of the dynamical local fluctuations. Within our theory we address directly the response functions and identify a quantum critical endpoint along the transition line separating distinct insulating phases, corresponding to the divergence of the orbital compressibility. We establish that the discontinuous TQPT is determined by a synergetic coupling between the charge and the orbital polarization fluctuations.
Finally, we discuss the universality of our results with respect to the specific choice of the microscopic Hamiltonian.

Symmetry-enforced Z_2 topology

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In this work, we study symmetry-enforced Z_2 topology in non-magnetic centrosymmetric materials in both regimes of strong and negligible spin-orbit coupling. We provide a classification of space groups, enforcing non-trivial topological Z_2 invariant. For the space groups, we list planes in the Brillouin zone that are topological at half-filling. The classification implies the existence of Dirac nodal lines for materials with negligible spin-orbit coupling. At the same time, the strong spin-orbit coupling opens a gap in the bulk. Due to the non-trivial Z_2 invariant, gapless symmetry-enforced states must emerge at the material surface. Also, we provide examples of materials for experimental observation.

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Twisted bilayer graphene at charge neutrality: competing orders of SU(4) Dirac fermions

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We study possible patterns for spontaneous symmetry breaking in a Dirac fermion model, which is applicable to twisted bilayer graphene at charge neutrality. We show how a chiral SU(4) symmetry emerges and construct the corresponding low-energy model that includes a Fierz-complete set of symmetry-allowed four-fermion interactions. We employ an unbiased renormalization group treatment to identify the critical points that describe transitions into different ordered phases. The resulting phase diagram depends on the number of fermion flavours and we show that the coupling between ordering channels prevents many of the possible mean-field orders from being accessible at relevant, small flavour numbers. We argue that, as a consequence, twisted bilayer graphene is governed by a quantum Hall state or an SU(4) manifold of insulating spin-valley orders with emergent Lorentz symmetry that contains inter-valley coherent, spin Hall, and valley Hall states.We study how SU(4)-breaking perturbations affect the accessibility and can additionally stabilize symmetry-broken (semi-)metallic states.

Pseudogap opening in the Hubbard model at strong coupling

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Using the recently introduced combination of the fRG with the DMFT, coined DMF2RG, we compute the frequency- and momentum-dependent self-energy of the two-dimensional Hubbard model at strong coupling. For this, we extend the single-boson exchange formulation of the fRG for the computation of the self-energy flow with the Schwinger-Dyson equation. This has shown to be essential to capture the pseudogap opening in the weak-coupling regime. We discuss the structure of the flow equations and present numerical results for the self-energy.

Thermoelectric transport of charged two-dimensional Dirac systems: the role of plasmons

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We study the roles of Coulomb interactions in transport properties of interacting Dirac electrons in two-dimensions. We study it from a weak-coupling and a strong-coupling perspective. We demonstrate that long-range Coulomb interactions play two independent roles. (i) In the weak-coupling analysis, they provide the inelastic and momentum-conserving scattering mechanism that leads to fast local equilibration which is a prerequisite for electron hydrodynamics. (ii) In the strong-coupling analysis, they facilitate the emergence of collective excitations, plasmons, that contribute to transport properties on equal footing with electrons. While the electron hydrodynamics has been studied intensively for many years, the role of plasmons in the transport properties of Dirac systems receives much less attention. In this work, we show that plasmons make a sizeable contribution to the thermal conductivity. While the increase at the Dirac point is moderate, it becomes large towards larger doping. We suspect, that this is a generic feature of ultraclean two-dimensional electronic systems, also applicable to degenerate systems. We suggested that this effect can be experimentally observed, for example, in graphene of which the effective fine-structure constant characterizing the strength of the Coulomb interactions is of order 1.

Dipole representation of half-filled Landau level: quantum Hall and its bilayers

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The formalism for composite fermions, initially developed for bosons at filling factor v = 1 [1, 2], has been a cornerstone in understanding the fractional quantum Hall effect (FQHE). We derive the Dirac composite fermion theory for a half-filled Landau level from first principles [3]. In this talk, we present novel insights into this phenomenon by employing a dipole representation for composite fermions that incorporates the symmetry under particle-hole exchange. By imposing a unique constraint on the degrees of freedom of composite fermions and composite holes within an enlarged space, we ensure that the resulting composite particles, known as dipoles, possess symmetric characteristics. Our investigation focuses on an effective Hamiltonian that commutes with the constraint in physical space while preserving boost invariance at the Fermi level. Remarkably, our calculations [4] of the Fermi liquid parameter F2 demonstrate remarkable agreement with previous numerical investigations [5]. Furthermore, we investigate the phase diagram of the quantum Hall bilayer (QHB) system at total filling factor v = 1, where physics at small interlayer distances is understood in terms of Bose-Einstein condensation (BEC), while at large distances, physics is mostly understood in terms of fermionic condensation. We have now shown that composite fermions offer an accurate description of the system for all distances [6].

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Electron correlations and spontaneous symmetry-breaking in twisted bilayer graphene

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We use dynamical mean-field theory to study the interplay of electron correlations and spontaneous symmetry-breaking in magic-angle twisted bilayer graphene. We find that there is no genuine Mott state—long-range order from spontaneous symmetry-breaking is essential to opening a gap at the Fermi level. We find that dynamic correlations strongly suppress ordering temperatures (by a factor of 10 compared to Hartree-Fock calculations). We characterise the momentum-resolved spectral functions and low energy quasiparticles as a function of filling in both the symmetry-broken and symmetric states. Our results provide a new understanding of the cascades seen in STM experiments as a sequence of Lifschitz transitions. Finally, we find a curious enhancement of correlations by order at certain values of doping close to integer filling.

Exceptional susceptibilities: How non-Hermitian topology protects correlation-induced phase instabilities

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We show how the stability conditions for a system of interacting fermions can be also expressed in terms of local two-particle correlators, instead of conventional derivatives of thermodynamic potentials. By inspecting the spectral representation of the generalized local charge susceptibility and its lowest negative eigenvalues, we first illustrate the applicability of this stability conditions for the phase-transitions of a multi-orbital model for strongly correlated electrons. As a second step, we investigate the intrinsic relation linking the thermodynamic instabilities to the local generalized susceptibilities on a more fundamental level. In particular, we show that these quantities possess intrinsic non-Hermitian matrix properties, solely due to Fermi-Dirac statistics and imaginary time-ordering, which enable the occurrence of exceptional points, i.e. singularities where two eigenvalues and eigenvectors coalesce. By means of both analytic and numerical approaches, we demonstrate that exceptional points promote the correlation-induced thermodynamic instabilities to a topologically stable phenomenon.

Quantics Tensor Cross Interpolation for High-Resolution, Parsimonious Representations of Multivariate Functions in Physics and Beyond

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Multivariate functions of continuous variables arise in countless branches of science. Numerical computations with such functions typically involve a compromise between two contrary desiderata: accurate resolution of the functional dependence, versus parsimonious memory usage. Recently, two promising strategies have emerged for satisfying both requirements: (i) The quantics representation, which expresses functions as multi-index tensors, with each index representing one bit of a binary encoding of one of the variables; and (ii) tensor cross interpolation (TCI), which, if applicable, yields parsimonious interpolations for multi-index tensors. Here, we present a strategy, quantics TCI (QTCI), which combines the advantages of both schemes. We illustrate its potential with an application from condensed matter physics: the computation of Brillouin zone integrals.

Antiferromagnetism and spin-orbit interaction driven spin splitting in centrosymmetric hexagonal MnTe

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Antiferromagnets with spin-split bands in the momentum space emerged as promising materials for technologies based on antiferromagnetic spintronics using spin-orbit or spin-splitting torque. The absence of bulk or structural inversion symmetry along with spin-orbit interaction leads to such spin-splitting known as Dresselhaus or Rashba effect, respectively. Spin-splitting phenomena occur even for compounds with low atomic numbers in the absence of combined inversion | time reversal and combined spin rotation | translation symmetries [1]. We identify a centrosymmetric material MnTe that exhibits both types of spin-splitting phenomena, making it interesting to study. Using a carefully chosen exchange-correlation functional and corrections, our calculations within density functional theory reveal an insulating state with a preferred antiferromagnetic order. To look into the magnetic behavior in detail, we have computed different exchange interaction strengths and estimated the magnetic ordering temperature via Monte Carlo calculations. Our calculation and symmetry analysis reveals a large spin-splitting in the system due to the antiferromagnetic order without considering spin-orbit interaction, except in the k_x-k_y plane. Critical examination of the band dispersion and the spin textures obtained from our calculation and a comparison with an insightful analytical model confirms the presence of a combined Rashba-Dresselhaus interaction around the high-symmetry K point in the k_x-k_y plane [2]. Further, we investigate the ferroelectric property of this system and find reasonable electric polarization in a higher-energy magnetic configuration. Our investigation uncovers the spin-splitting phenomena with and without spin-orbit coupling, making it a promising candidate for technological applications.

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Magnetism in the two-dimensional dipolar XY model

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Motivated by a recent experiment on a square-lattice Rydberg atom array realizing a long-range dipolar XY model [Chen et al., Nature (2023)], we numerically study the model's equilibrium properties. We obtain the phase diagram, critical properties, entropies, variance of the magnetization, and site-resolved correlation functions. We consider both ferromagnetic and antiferromagnetic interactions and apply quantum Monte Carlo and pseudo-Majorana functional renormalization group techniques, generalizing the latter to a U(1) symmetric setting. Our simulations open the door to directly performing many-body thermometry in dipolar Rydberg atom arrays. Moreover, our results provide new insights into the experimental data, suggesting the presence of intriguing quasi-equilibrium features, and motivating future studies on the non-equilibrium dynamics of the system.

The zoo of states in the two-dimensional Hubbard model

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Pietro Maria Bonetti, Demetrio Vilardi, Walter Metzner

We use real-space Hartree-Fock theory to construct a magnetic phase diagram of the two-dimensional Hubbard model as a function of temperature and doping. We are able to detect various spin- and charge order patterns including Néel, stripe and spiral order without biasing the system towards one of them. For an intermediate interaction strength we predominatly find Néel order close to half-filling, stripe order for low temperatures or large doping, and an intermediate region of spiral order.

How Cosmic Inflation Solves the Magnetic Monopole Problem?

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According to the big bang theory, the universe began as an extremely hot, dense, and small point known as singularity. Approximately 13.8 billion years ago, this singularity began to expand and cool, eventually forming subatomic particles, atoms, stars, galaxies, and eventually the structure of the universe as we know it today. At that time, the universe was formed from the stage of nothingness since there was no time available before the Big Bang for any known matter to exist. There was a minute imbalance condition in the very early hours of the Big Bang that caused matter to win the race over antimatter. Mathematically this discrepancy was due to one extra matter for every 1 billion matter-antimatter created. But what exactly caused this extra matter to appear? Proton annihilation is a hypothetical process in which protons, subatomic particles that make up the nuclei of atoms, come into contact and annihilate each other, releasing a large amount of energy in the process. Here comes the "monopole problem", which refers to the fact that if magnetic monopoles existed in the early universe, they would have been produced in such large numbers that they would have a much higher density than what is observed today. This would have resulted in a universe that would have been magnetically dominated and would have prevented the formation of galaxies, stars, and planets. This problem refers to the fact that if magnetic monopoles existed in the early universe, their density would have been much higher than what is observed today, preventing the formation of galaxies, stars, and planets. But the Universe metamorphosed itself in an unconventional manner which is a hot-selling cake-like topic in modern astronomy and physical sciences. The study tries to evaluate different processes through cosmic inflation that took place over the course of time in the universe and find the reason for the monopole dilemma and its unstable low-density existence.

Disorder effects in the Kitaev-Heisenberg model

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We study the interplay of disorder and Heisenberg interactions in the Kitaev model on a honeycomb lattice. The effect of disorder on the transition between Kitaev spin liquid and magnetic ordered states as well as the stability of magnetic ordering is investigated. Using Lanczos exact diagonalization we discuss the consequences of two types of disorder: (i) random-coupling disorder and (ii) singular-coupling disorder. They exhibit qualitatively similar effects in the pure Kitaev-Heisenberg model without long-range interactions. The range of spin-liquid phases is reduced and the transition to magnetic ordered phases becomes more crossoverlike. Furthermore, the long-range zigzag and stripy orderings in the clean system are replaced by their three domains

with different ordering direction. Especially in the crossover range the coexistence of magnetically ordered and Kitaev spin-liquid domains is possible. With increasing the disorder strength the area of domains becomes smaller and the system goes into a spin-glass state. However, the disorder effect is different in magnetically ordered phases caused by long-range interactions. The stability of such magnetic ordering is diminished by singular-coupling disorder and, accordingly, the range of the spin-liquid regime is extended. This mechanism may be relevant to materials like α-$RuCl_3$ and $H_3LiIr_2O_6$ where the zigzag ground state is stabilized by weak long-range interactions. We also find that the flux gap closes at a critical disorder strength and vortices appears in the flux arrangement. Interestingly, the vortices tend to form kinds of commensurate ordering.

Quantum phase transitions in non-Hermitian PT-symmetric Ising spin chains

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The study of the simple spin models provides an insight into the nature of phase transitions. Given the growth of the attention to the non-Hermitian systems in the recent years, it is interesting to look into phase transitions in non-Hermitian systems.

Here, I present a theoretical study of quantum phases and quantum phase transitions occurring in non-Hermitian transverse-field Ising spin model. A non-Hermitian part of the Hamiltonian is implemented via imaginary staggered longitudinal magnetic field corresponding to a local staggered gain and loss terms, γ, which guarantees PT-symmetry of the system

Using a numerical diagonalization of the Hamiltonian for spin chains of a finite size N accompanied by a scaling procedure for the coherence length ξ, a complete quantum phase diagram γ-J (J is an adjacent spins interaction strength) is established. We obtain two quantum phases for $J < 0$, i.e., PT-symmetry broken (complex eigenvalues) antiferromagnetic state and PT-symmetry preserved (real eigenvalue) paramagnetic state, which are separated by the line of Exceptional points. For $J > 0$, the PT-symmetry of the ground state is retained in a whole region of parameter space of J and γ, and a system shows two intriguing quantum phase transitions between ferromagnetic and paramagnetic states for a fixed parameter $\gamma > 1$.

Driven Hubbard Model on a Triangular Lattice: Tunable Heisenberg Antiferromagnet with Multiple Ordered and Disordered Phases

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We study the effects of a periodically varying electric field on the Hubbard model at half-filling on a triangular lattice. The driving electric field is incorporated through the phase of the nearest-neighbor hopping amplitude via the Peierls prescription. When U is much larger than the hopping, the system is a Mott insulator and the effective Hamiltonian $Heff$ describing the spin sector can be found using a Floquet perturbation theory. To third order in the hopping, $Heff$ is found to have the form of a Heisenberg antiferromagnet with three different nearest-neighbor couplings ($J\alpha$,$J\beta$,$J\gamma$) on bonds lying along the different directions. Remarkably, when the periodic driving does not have time-reversal symmetry, $Heff$ can also have a chiral three-spin interaction in each triangle, with the coefficient C of the interaction having opposite signs on up- and down-pointing triangles. Thus periodic driving which breaks time-reversal symmetry can simulate the effect of a perpendicular magnetic flux which is known to generate such a chiral term in the spin sector, even though our model does not have a magnetic flux. The four parameters ($J\alpha$,,,) depend on the amplitude, frequency and direction of the oscillating electric field. We then study the spin model as a function of these parameters using exact diagonalization and find a rich phase diagram of the ground state with seven different phases consisting of two kinds of ordered phases (collinear and co-planar) and disordered phases. Thus periodic driving of the Hubbard model on the triangular lattice can lead to an effective spin model whose couplings can be tuned over a range of values thereby producing a variety of interesting phases.

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Quantum restoration of Symmetry Protected Topological phases

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Fermionic Symmetry Protected Topological (SPT) phases can be destroyed by spontaneous symmetry breaking. However, particularly in low dimensions, strong quantum fluctuations may destroy local order parameters and thereby, potentially restoring the SPT phase. To illustrate this phenomenon, we present a study of a model comprising SSH chains coupled to Cooper pair boxes at different fillings (half filling and quarter filling) using a combination of analytical (bosonization, renormalization group, effective field theories) and numerical (DMRG) techniques. At half-filling, our analysis reveals that, despite the absence of gap closing in mean field theory, the inclusion of strong quantum fluctuations leads to a gap closure between non-interacting topological and trivial phases, indicating a probable restoration of the Symmetry Protected Topological (SPT) phase. Furthermore, we investigate the system at quarter filling, considering its potential in quantum technologies, and find a rich phase diagram. Our results underscore the significance of accounting for quantum fluctuations in understanding the true nature of quantum systems and reveal intriguing possibilities for topological phase restoration and quantum technological advancements.

Magnetism and metallicity in moiré transition metal dichalcogenides

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Recent experiments on moiré transition metal dichalcogenides have established this class of compounds as a highly tunable platform for the study of correlated electronic phenomena such as the correlation-driven Mott metal-insulator transition, quantum criticality and superconductivity. At the same time these materials can be approximately described in terms of the single-band moiré Hubbard model on a triangular lattice. We investigate the properties of this model at half-filling, where it hosts a variety of metallic, insulating and magnetic phases and we study in detail their interplay with an externally applied Zeemann field.
At finite temperatures we employ the dynamical mean-field theory (DMFT) and its cluster extensions CDMFT and DCA in order to capture both local and non-local correlations, while at T=0 the recently developed Variational Discrete Action Theory (VDAT) is used to elucidate the polarization transition.

Larmor precession in strongly correlated itinerant electron systems

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Lund University

Many-electron systems undergo a collective Larmor precession in the presence of a magnetic field. In a paramagnetic metal, the resulting spin wave provides insight into the correlation effects generated by the electron-electron interaction. Here, we use dynamical mean-field theory to investigate the collective Larmor precession in the strongly correlated regime, where dynamical correlation effects such as quasiparticle lifetimes and non-quasiparticle states are essential. We study the spin excitation spectrum, which includes a dispersive Larmor mode as well as particle-hole excitations that lead to Stoner damping. We also extract the momentum-resolved Gilbert damping of slow spin waves. The accurate theoretical description of these phenomena relies on the Ward identity, which guaranteees a precise cancellation of self-energy and vertex corrections at long wavelengths.

Synthesis and characterization of carbon quantum dots: comparison with calculation by DFTB+

Jorge Joe Espinosa Ventura

Center for advanced studies

Ariel Castro Sifontes, Fernando Guzmán Martínez, Yarima García ,
Ronaldo Hernández Mendes

Carbon quantum dots (CQD) represent one of the recently discovered allotropic forms of carbon whose quantum confinement properties give it certain peculiarities in terms of its behavior. In these structures, the close relationship established between optoelectronic properties such as absorbance, fluorescence, and the presence of functional groups at their edges is well known. Associated with the above, in recent years common points have been observed between these nanomaterials and semiconductor quantum dots (QD). Despite the above, there is still no established theory capable of correctly explaining fluorescence, or its dependence on the emission wavelength, which is why computational modeling must be used to predict the properties and behavior of fluorescence. these settings. Based on the information obtained from characterization techniques of samples synthesized at the Center for Advanced Studies of Cuba (CEA) that provides precise information on their structure and behavior, in the present work some of the properties of primary CQD formations such as the band structure and the dependence of the size of the material with the emission wave, using the Density Functional Theory with Strong Bond Approximation (DFTB).

Magnetic and pairing fluctuations in the gauge theory of the Pseudogap phase

Demetrio Vilardi

MPI for Solid State Research

Pietro Maria Bonetti

We analyze the interplay of fluctuating antiferromagnetism and pairing in the two dimensional Hubbard model with a moderate repulsive interaction. In particular, we present a gauge theory description for fluctuations where the stiffnesses are computed in the coexisting phase from renormalization mean-field equations via the functional renormalization group (fRG). We show a sizable doping regime with robust pairing coexisting with Néel or incommensurate antiferromagnetism. The fluctuations suppress any magnetic order at finite temperature while the Kosterlitz-Thouless critical temperature for pairing remains finite.

Designing Fractionalized Topological Phases by Quantum Geometry

Jie Wang

Harvard University

Moiré materials produced by stacking monolayers with small relative twist angles are of intense current interest for the range of correlated electron phenomena they exhibit and for their high degree of experimental controllability. Controlling moiré to realize exotic quantum phase of matter is important for both fundamental science research and future application to quantum information sciences. This talk focus on the fractional Chern insulator phase, the analogy of fractional quantum Hall effect in the absence of external magnetic fields.

The common wisdom is to engineer material to approach Landau level limit to stabilize fractional Chern insulators. This talk will disprove such common lore by showing a new theory (ideal flatband theory) which emphasizes the fundamental importance of quantum geometries of wavefunctions. The new theory points to a large family of flatband systems that stabilize fractional Chern insulators exactly beyond the conventional Landau level limit. It has a wide range of application to 2D material design, including twisted bilayer graphene, moiré TMD material, vortex lattice systems and others. It had direct implication for the recently experimental observed fractional Chern insulator in twisted bilayer graphene samples.

Spin-Peierls instability of the U(1) Dirac spin liquid

Josef Willsher

TU Munich

Frank Pollmann, Markus Drescher, Johannes Knolle, Urban F. P. Seifert

Quantum spin liquids are tantalizing phases of quantum matter, but experimental evidence of their existence has remained elusive. Even theoretically, it is unclear whether many phases permitted by a mean-field classification can be realized as the stable ground states of a physical model. Recent theoretical and numerical studies have provided evidence that triangular-lattice Heisenberg antiferromagnets could host a U(1) Dirac spin liquid (DSL). This strongly coupled phase of matter with gapless spinon and gauge excitations is a two-dimensional analog of the Luttinger liquid description of the antiferromagnetic Heisenberg chain and its spin-disordered ground state. In this work, we find a spin-Peierls instability upon infinitesimal coupling of the DSL to a static lattice distortion. In analog to the Luttinger liquid, we find that explicitly breaking translational symmetry allows a relevant instanton to appear in the effective action – in our case, a lattice-monopole term. We calculate the effective free energy using conformal perturbation theory and show that an infinitesimal static coupling destroys the quantum spin-disordered ground state, resulting in a gapped 12-site valence bond solid with commensurate lattice distortion. Away from the static-distortion limit, we show that the possibility of establishing a DSL phase in experiment depends critically on the relationship between the lattice coupling and phonon frequency since there is a weak-coupling regime within which the spin-liquid phase remains stable. Our work presents a novel extension of the spin-Peierls mechanism to two-dimensional interacting fermions, which has profound implycations for the stability and observability of general spin liquid states with gapless gauge excitations.

Coherence and pairing fluctuations in strongly correlated superconductors

Niklas Witt

University of Hamburg

Yusuke Nomura, Sergey Brener, Ryotaro Arita, Alexander I. Lichtenstein, Tim O. Wehling

The fundamental properties of superfluids and superconductors are determined by the spatial coherence of the macroscopic condensate. Its fluctuations are pivotal to supercurrent flow, the functionality of superconducting nanostructures, and the response superconducting matter shows to magnetic fields. Central to a theoretical description is the coherence length which sets the relevant length scales of fluctuation effects. While a microscopic link is well established in weak-coupling BCS theory and Eliashberg-theory, it is a generally unknown quantity in strongly correlated superconductors where spatiotemporal fluctuations influence the critical temperature [1] and might underlie light-induced enhancement of superconductivity [2].
Here, we establish a link to directly calculate the coherence length as well as depairing currents and critical fields for superconductors with strong electron correlations from microscopic theories and first principles. We illustrate with the example of Alkali-doped fullerides (A_3C_{60}) how proximity of superconducting and Mott-localized states impact superconducting coherence, pairing localization, and critical temperature.

References

[1] Emery & Kivelson, Nature 374 (1995).
[2] Fausti et al., Science 331 (2011); Mitrano et al., Nature 530 (2016).

Multi-orbital phenomenology within the ghost Gutzwiller approximation

Carlos Mejuto Zaera

SISSA

Michele Fabrizio

In the pursuit towards targeted material design leveraging strong electronic correlation, computationnally inexpensive yet qualitatively reliable methods play a fundamental role. These approaches should allow for a rapid mapping of phase space, unveiling a first impression of possible phases of matter, which can then be explored in selected regions of parameter space with more accurate yet involved techniques. Recently, the ghost Gutzwiller Approximation (gGA) has been shown to be an interesting candidate for this kind of phenomenological search. Based on a self-consistency condition for the simple one-body reduced density matrix of a discretized impurity model, this method can capture spectral features of both coherent and incoherent nature in the one-body Green's function. In this work we assess its reliability in the multi-orbital regime, investigating systems presenting orbital-selective Mott transitions, Mott-to-band insulator transitions, and interaction-resilient Hund metallicity. Our results paint a promising picture for the potential of gGA for modelling of complex materials, possibly in combination with ab-initio methods.

Bus Shedule

Max Planck Institutes → University
Mon. – Fr.

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Linie 84 | 91 | 92 | X74 | 747 | 748

University → Max Planck Institutes
Mon. – Fr.

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Max Planck Institutes → Vaihingen ZOB 2023

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Linie 81

Vaihingen ZOB 2023
→ Max Planck Institutes

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6	08	24	39	49	59		
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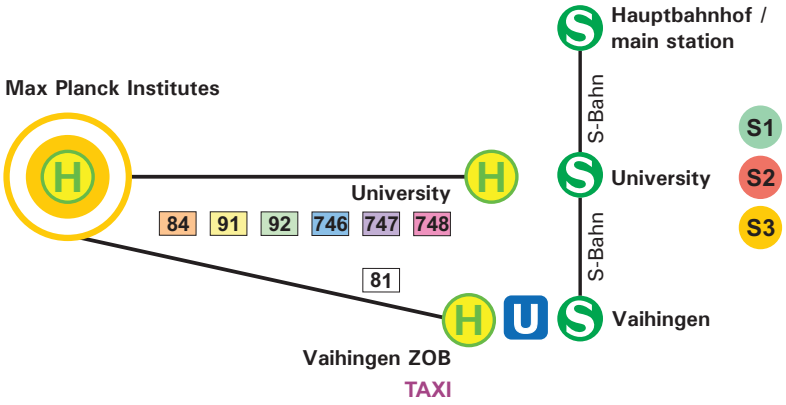
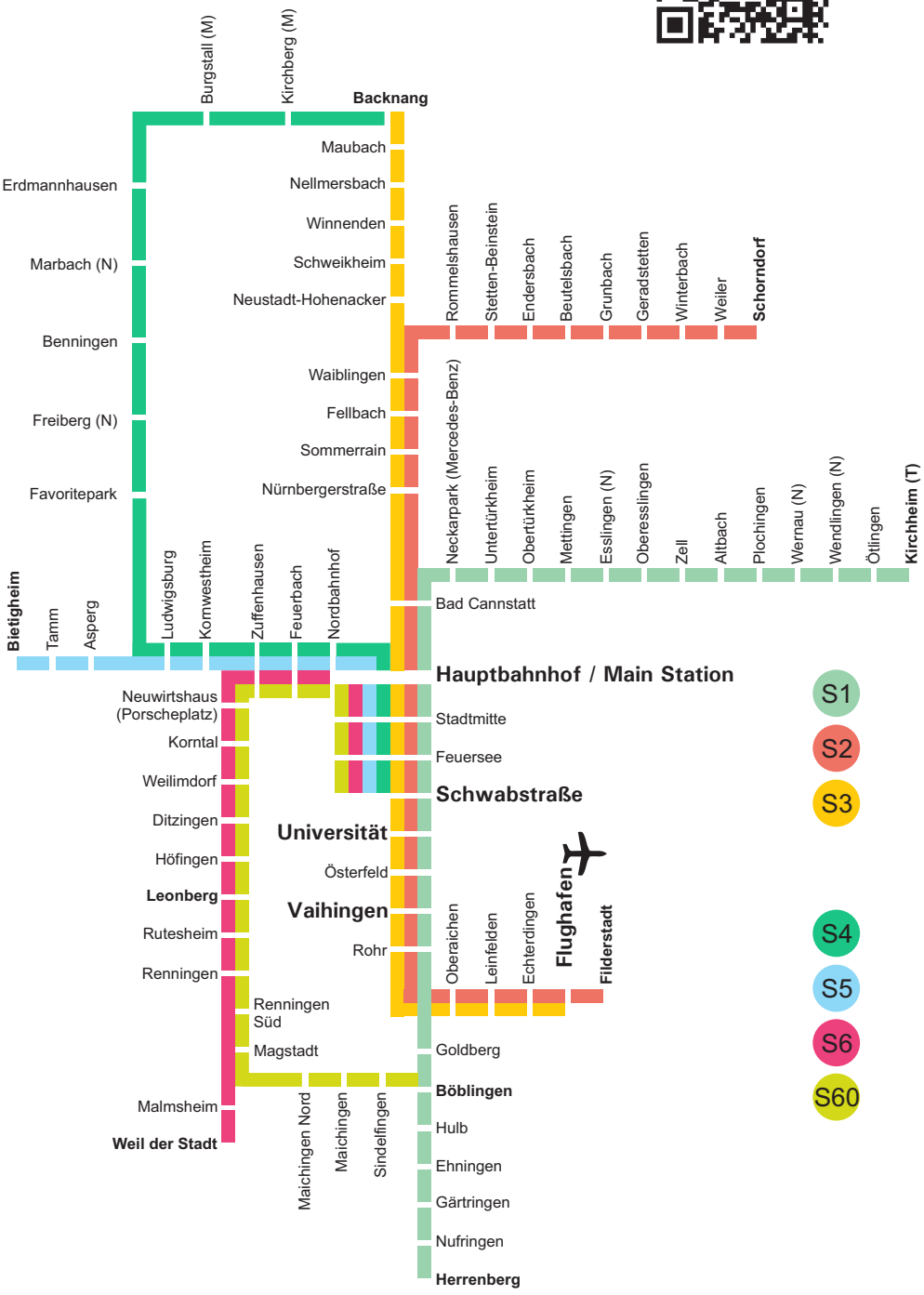
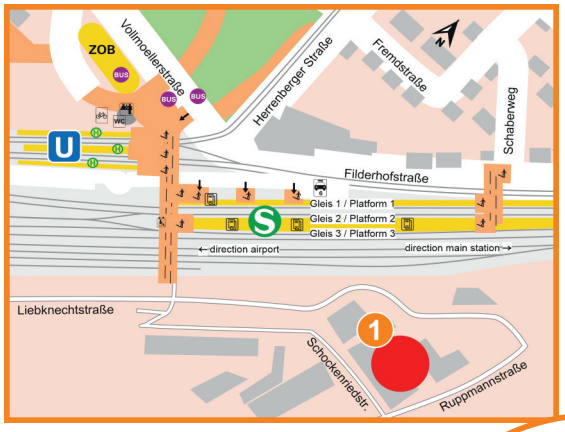
every 10 Min.

Linie 81



S-Bahn Map





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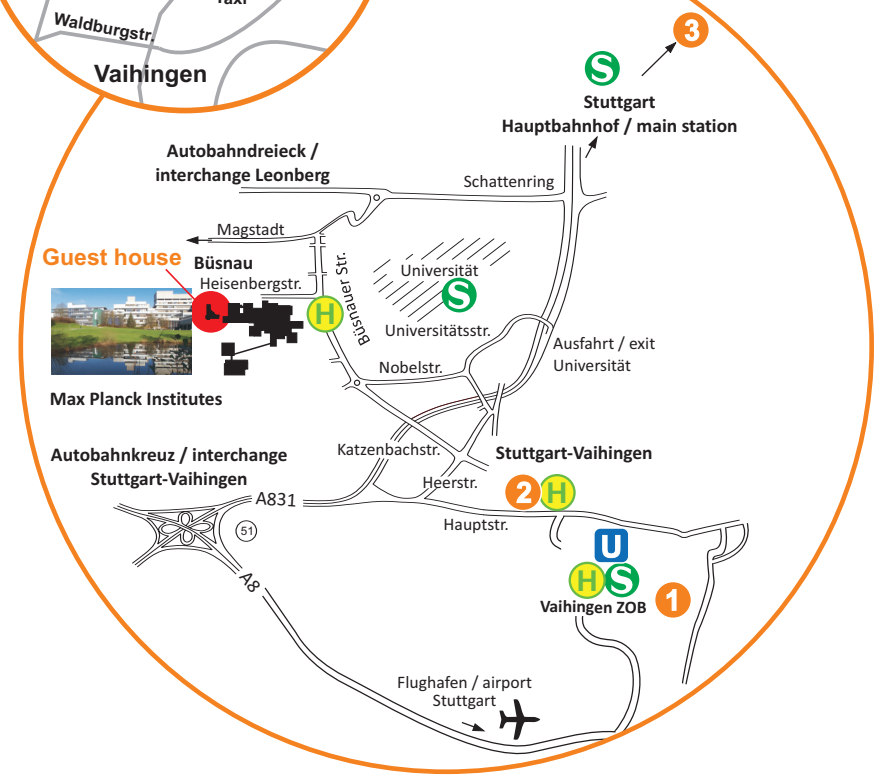
Bus Nr. 81

Hotels & Restaurants



3 Trödler zur Burgschenke

Auf der, Burg 1
73728 Esslingen am Neckar
Phone: +49/711/355 558

S-Bahn to Esslingen

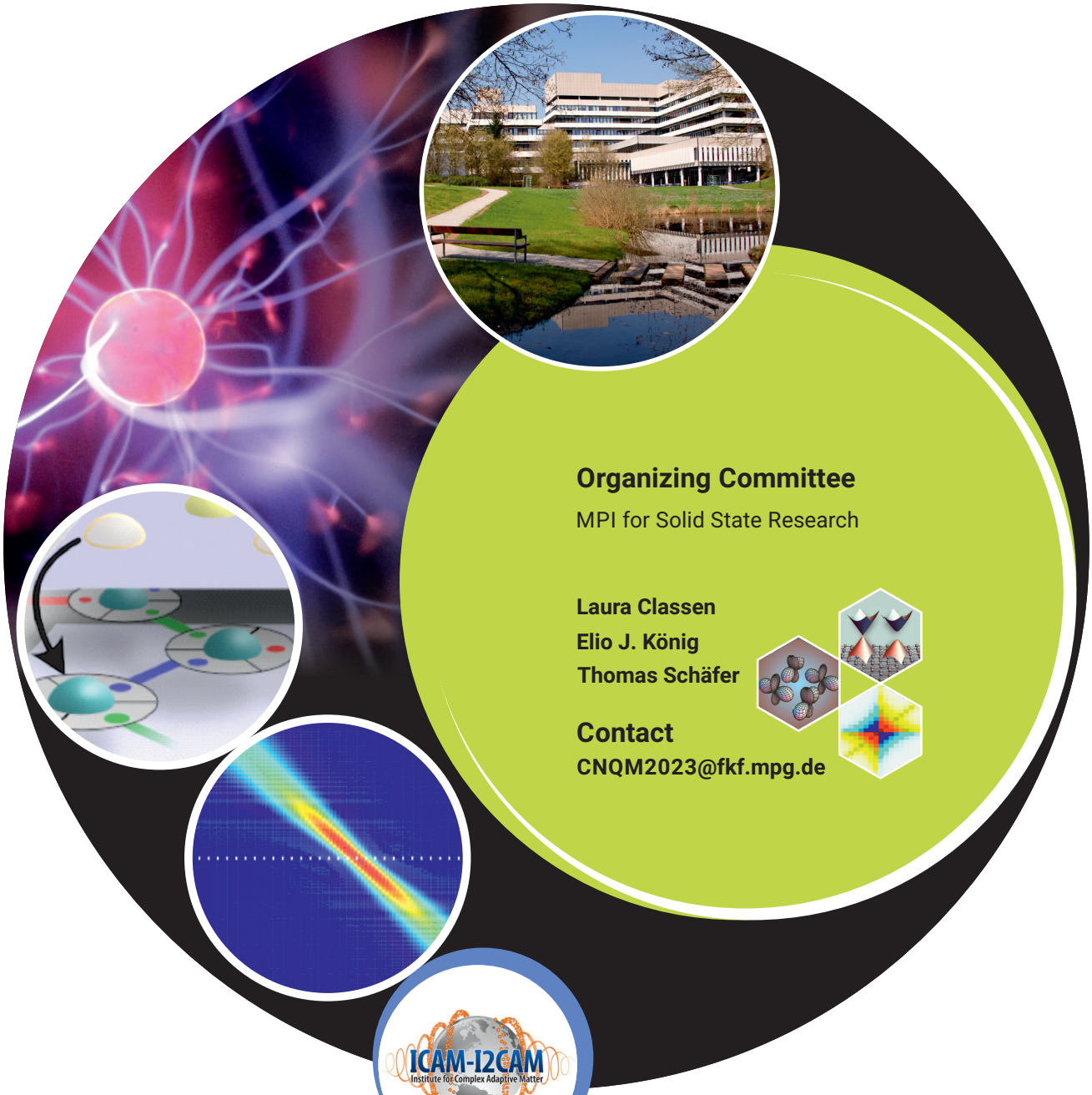
Restaurants

Near MPI Büsnau: Trattoria **Da Franco** (Italian) Adolf-Engster-Weg 10, 70569 Stuttgart, ✆ +49/711/681 704
Katzenbacher Hof (large beer garden), Katzenbacher Hof 1, 70569 Stuttgart

Near S-Bahn Schwabstraße: Ristorante **Goldoni** (Italian), Reinsburgstraße 151, 70197 Stuttgart, ✆ +49/711/659 988 9
Italo Disco (Italian), Augustenstraße 70, 70178 Stuttgart, ✆ +49/711/414 927 91
TAVERNA (Greek), Reinsburgstraße 102, 70197 Stuttgart, ✆ +49/711/504 818 88
Taverna Yol (Turkish), Spittastraße 2, 70193 Stuttgart, ✆ +49/711/636 325 6

Near S-Bahn Feuersee: **Trollinger** (large beer garden), Rotebühlstraße 50, 70178 Stuttgart, ✆ +49/711/621 441

Downtown: **Carls Brauhaus**, Schlossplatz, Stuttgart Mitte, ✆ +49/711/259 746 11
KICHO (Japanese), Jakobstraße 19, 70182 Stuttgart, ✆ +49/711/247 687
Ochs'n Willi, Kleiner Schlossplatz / am Königsbau, Stuttgart Mitte, ✆ +49/711/226 519 1
Tschechen & Söhne (large beer garden), Humboldtstraße 44, 70178 Stuttgart
Markthalle: Near the Königsbau, direction Rathaus, you 'll find the Market Hall, Dorotheenstraße 4, one of the most beautiful market halls in Germany. Built 1912 − 1924, renovated in 1993. Restaurant **Marktstüble** provides typical German specialities, there is also an Italien restaurant inside, **the Empore** and a **Tapas Bar**.
Near the Market Hall direction to the Rathaus, you will find a lot of good small restaurants.



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