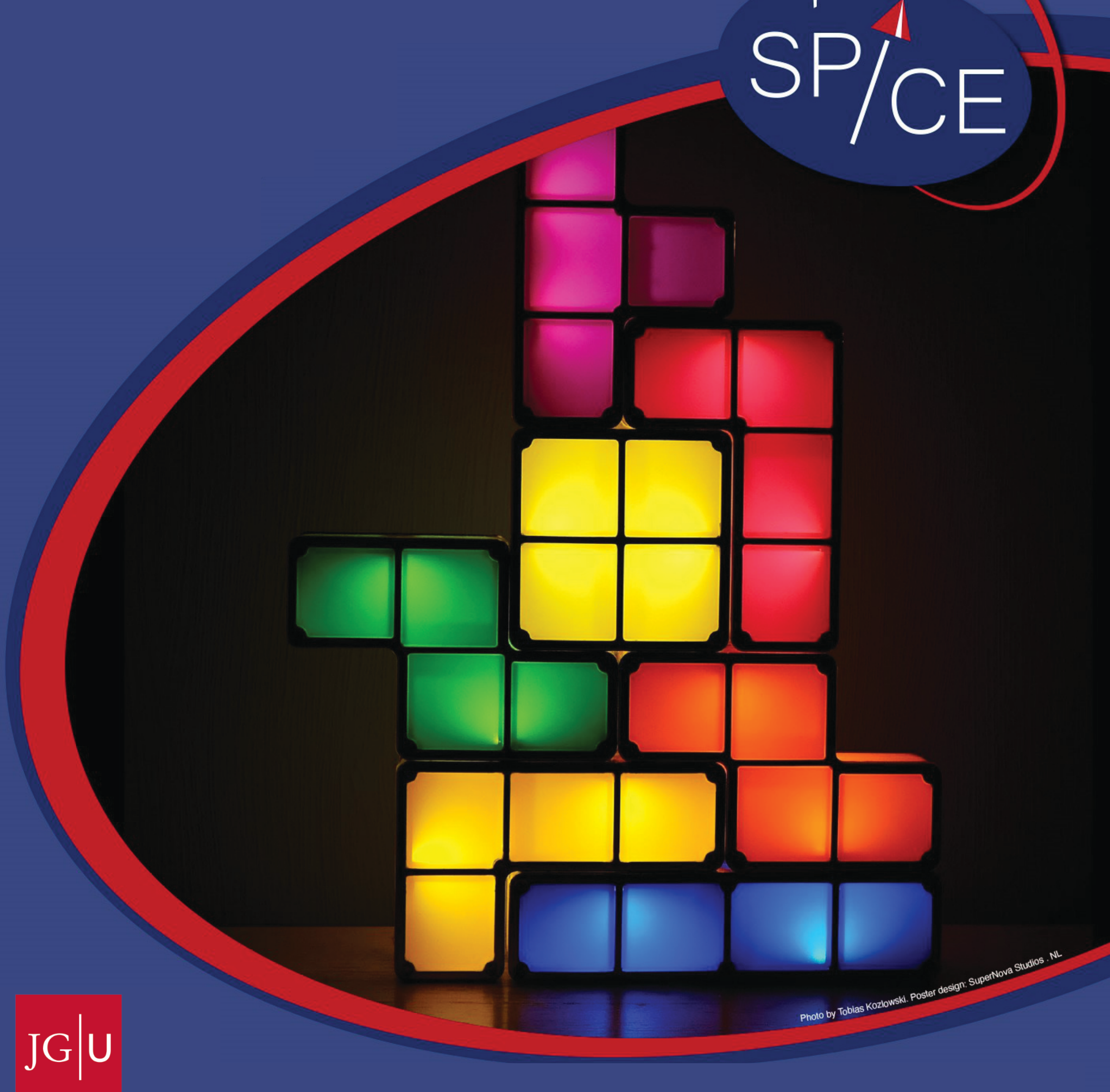
SPICE Workshop

May 24th - 26th 2022, Mainz, Germany

NEW SPIN ON MOLECULAR QUANTUM MATERIALS



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NEW SPIN ON MOLECULAR QUANTUM MATERIALS

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Program

Afternoon Session – Tuesday, May 24th

Quantum Systems and Simulations - Chair: Roser VALENTÍ

12:30 – 13:00	**Registration**
13:00 – 13:15	**Opening Remarks**
13:30 – 14:30	**Jörg SCHMALIAN, Karlsruhe Institute of Technology** Strain tuning through critical points
14:30 – 15:10	**Gabriel AEPPLI, ETH Zurich** Controlling spins and their interactions in molecular materials
15:10 – 15:50	**Hans Peter BÜCHLER, Stuttgart University** Quantum simulation of spin systems with Rydberg atoms
15:50 – 16:50	**Coffee Break**

Lattice effects in frustrated Mott insulators - Chair: Jens MÜLLER

16:50 – 17:50	**Michael LANG, Goethe University Frankfurt** Probing lattice effects in molecular spin-liquid-candidate systems
17:50 – 18:30	**Elena GATI, MPI CPfS** Exploring the coupling of Mott insulators to elastic degrees of freedom by pressure tuning
19:00	**Dinner at Restaurant WASEM**

Morning Session – Wednesday, May 25th

Frustration and disorder on triangular lattices - Chair: Martin DRESSEL

09:00 – 10:00	**Kazushi KANODA, University of Tokyo** Emergent states of interacting electrons on triangular lattices
10:00 – 10:40	**Coffee Break and Poster Session**
10:40 – 11:20	**Kenichiro HASHIMOTO, University of Tokyo** Randomness effect on charge glass formation in θ-type BEDT-TTF compounds
11:20 – 12:00	**Tatjana THOMAS, Goethe University Frankfurt** Slow Dynamics in the Charge-Glass Forming Organic Conductors - (BEDT-TTF)2MM’(SCN)4
12:00 – 12:40	**Natalia DRICHKO, Johns Hopkins University** Interplay of charge and spin degrees of freedom in triangular lattice dimerized molecular Mott insulators
12:40 – 14:00	**Lunch Break**

Afternoon Session – Wednesday, May 25th

Quasi One-Dimensional Systems - Chair: Elena GATI

14:00 – 15:00	**Thierry GIAMARCHI, University of Geneva** Transport in quasi-one dimensional systems
15:00 – 15:30	**Poster Flash Presentation**
15:30 – 16:30	**Poster Session**
16:30 – 18:00	**Vineyard Excursion**
18:15 – 18:30	**Jairo's Online Wine Presentation**
18:30	**Dinner at Restaurant WASEM**

Morning Session – Thursday, May 26th

From Mott Insulators to Bad Metals and Fermi Liquids - Chair: Joerg SCHMALIAN

09:00 – 10:00	**Antoine GEORGES, Collège de France** Frustrated and Correlated: Metal Insulator Transitions on Triangular Lattices
10:00 – 10:30	**Coffee Break and Poster Session**
10:30 – 11:10	**Louk RADEMAKER, University of Geneva** Fake Insulators: What are they, and how to spot them?
11:10 – 11:50	**Simone FRATINI, CNRS** Bad metal behavior from slow collective excitations
11:50 – 12:30	**Kamran BEHNIA, ESPCI Paris** T-square thermal resistivity and quasi-particle hydrodynamics
12:30 – 13:30	**Lunch Break**

Afternoon Session – Thursday, May 26th

QSL in honeycomb materials - Chair: Steve WINTER

13:30 – 14:30	**Hidenori TAKAGI, MPI for Solid State Research** Towards Kitaev Quantum Spin Liquid
14:30 – 15:00	**Coffee Break and Poster Session**
15:00 – 15:40	**Jaime MERINO, University of Madrid** Quantum spin liquids and superconductivity in honeycomb molecular materials
15:40 – 16:20	**Masahiko G. YAMADA, Osaka University** SU(4) materials: emergence and developments
16:20 – 18:00	**Discussion Time and Poster Session**
18:00 - 19:30	**Dinner at Restaurant WASEM**

Dynamics of Correlations - Chair: Andrej PUSTOGOW

19:30 – 20:10	**Stefan KAISER, TU Dresden** Higgs Spectroscopy in superconductors
20:10 – 21:10	**Andrea CAVALLERI, MPI Structure and Dynamics of Matter** New Physics in Driven Quantum Materials
21:10	**Closing Remarks**

Speaker Abstracts

Tuesday, May 24th, 13:30

Strain tuning through critical points

Jörg SCHMALIAN
Karlsruhe Institute of Technology

Manipulating quantum materials via varying external strain has become a powerful tool to manipulate and probe systems as diverse as iron-based superconductors, cuprates, strontium ruthenate, and organic charge transfer salts. Particularly interesting behaviour occurs as strain is used to tune through a phase transition or a critical point. In this talk I will give an overview of the various regimes of strain tuning with systems where strain couples directly to the order parameter or rather to the energy density at the transition. Examples of the former include Mott critical points and nematic transitions, while the latter occurs at certain magnetic or Lifshitz transitions. We discuss phenomena like strain-induced elastic interactions and a new, generalised quantum Harris criterion where strain coupling changes the universality class of a quantum phase transition..

Tuesday, May 24th, 14:30

Controlling spins and their interactions in molecular materials

Gabriel AEPPLI
ETH Zurich

A key challenge both for fundamental non-equilibrium science as well as eventual applications, most visibly to quantum computing, is the control of individual spin states and their interactions. Traditionally, the interactions are regulated by chemical means or pressure, while magnetic resonance paradigms are applied to individual spins. Approaches for more rapid setting of individual spin states and modulation of interactions, while maintaining long decoherence times after intervention, are obviously required, and we describe research on spin-carrying entities which will allow the design of such approaches.

[1] Grimm et al. PRX Quantum 2, 010312 (2021)
[2] Wu et al. Adv. Funct. Mater. 29, 1902550 (2019)

Tuesday, May 24th, 15:10

Quantum simulation of spin systems with Rydberg atoms

Hans Peter BÜCHLER
Stuttgart University

The concept of topological phases is a powerful framework for characterizing ground states of quantum many-body systems that goes beyond the paradigm of symmetry breaking. Topological phases can appear in condensed-matter systems naturally, whereas the implementation and study of such quantum many-body ground states in artificial matter require careful engineering. In this talk, we review different approaches for the realization of topological phases with Rydberg atoms. Starting with the recent experimental observation of a symmetry protected topological phase, we extend the approaches into two dimensions on fractional bosonic Chern insulators. The required experimental setup is based on atoms trapped in an array of optical tweezers and excited into Rydberg levels, which gives rise to hard-core bosons with an effective hopping generated by dipolar exchange interaction.

Tuesday, May 24th, 16:50

Probing lattice effects in molecular spin-liquid-candidate systems

Michael LANG
Goethe University Frankfurt

κ-phase (BEDT-TTF)2X salts reveal a layered structure where (BEDT-TTF)21+ dimers form a distorted triangular lattice. The systems show a wide variety of intriguing phase transitions and ground states including the Mott metal-insulator transition, quantum disordered potentially quantum-spin-liquid (QSL) phases, local moment antiferromagnetic and charge-ordered states as well as superconductivity. Crucial parameters, determining the actual ground state, are the relative strength of onsite-, intersite- and intradimer Coulomb interactions, the degree of frustration and the coupling of the electronic degrees of freedom to the lattice.

In this talk we will address the QSL-candidate systems κ-(BEDT-TTF)2X with X = Cu2(CN)3 and Ag2(CN)3, both of which are characterized by a high degree of frustration and the lack of long-range magnetic order down to mK temperatures. In particular, we will address the mysterious 6 K anomaly for the X = Cu2(CN)3 salt where thermal expansion measurements [1,2] revealed clear evidence for a second-order phase transition with strong involvement of the lattice degrees of freedom, recently assigned to the formation of valence-bond singlets [3]. These observations will be complemented by recent results of an inelastic-neutron-scattering study on deuterated specimens of X = Cu2(CN)3 [4], probing the same intra-dimer breathing/shearing mode where pronounced renormalization effects accompanying ordering phenomena in the spin- and charge-channels, were revealed for the dimer-Mott insulator X = Cu[N(CN)2]Cl [5]. In contrast, for the X = Ag2(CN)3 system, the thermal expansion lacks any indication for a phase transition down to 1.5 K, consistent with a QSL ground state. For this system directional-dependent broad anomalies are observed around 20 K which can be assigned to the strongly correlated π-electron system on a triangular lattice [6].

[1] R. S. Manna et al., Phys. Rev. Lett. 104, 016403 (2010)
[2] R. S. Manna et al., Crystals 8, 87 (2018)
[3] B. Miksch et al., Science 372, 276 (2021)
[4] M. Matsuura et al., in preparation
[5] M. Matsuura et al., Phys. Rev. Lett. 123, 027601 (2019)
[6] S. Hartmann et al., Phys. Status Solidi B 256, 1800640 (2019)

Tuesday, May 24th, 17:50

Exploring the coupling of Mott insulators to elastic degrees of freedom by pressure tuning

Elena GATI
MPI CPfS

Organic charge-transfer salts are considered as prime examples to study the wealth of phenomena that arise from strong electronic correlations, given their large tunability that makes their intriguing physics accessible in laboratory settings. In recent years, it also became clear that they are ideal candidate systems to explore the role of electron-lattice coupling in correlated materials, since they are very amenable to pressure tuning. For example, we demonstrated that the universal properties of the pressure-driven Mott metal-insulator transition in □-(BEDT-TTF)2Cu[N(CN)2]Cl are governed by “critical elasticity”, i.e., the coupling of the critical electronic subsystem to the crystal lattice [1].

After reviewing these results on the organic charge-transfer salts, I will focus on manifestations of electron-lattice coupling in inorganic materials, that are revealed by pressure tuning [2], in the main part of my talk. Specifically, I will discuss the example case of ferromagnetism in the Mott insulator VI3 in which hydrostatic pressure stabilizes symmetry-breaking structural distortions that are responsible for a doubling of the ferromagnetic transition temperature by the application of moderate hydrostatic pressures [3]. I will also introduce how modern uniaxial pressure devices, that can be used to deliberately break symmetry, allow to determine the elastocaloric effect [4]- a quantity that is a direct manifestation of electron-lattice-coupling - and discuss its applicability for the study of strongly correlated Mott insulators in the future.

[1] E. Gati et al., Science Advances 2, 1601646 (2016)
[2] E. Gati et al., Annalen der Physik 532, 2000248 (2020)
[3] E. Gati et al., Phys. Rev. B 100, 094408 (2019) (Editor's Suggestion)
[4] M. Ikeda et al., Rev. Sci. Inst. 90, 083902 (2019)

Wednesday, May 25th, 09:00

Emergent states of interacting electrons on triangular lattices

Kazushi KANODA
University of Tokyo

Triangular lattices are uncomfortable stages for interacting electrons, however, which bring about emergent states. In half-filled band systems, antiferromagnetically interacting spins are strongly frustrated and may exhibit a quantum spin liquid (QSL). In quarter-filled band systems, Coulomb interacting electrons fail to form a Wigner crystal on a triangular lattice but may freeze into a charge glass (CG) state. The kappa-ET salts and theta-ET salts are good model systems for the former and latter subjects, respectively. In this workshop, I will present our updated results on these two issues.

For the issue of QSL, I summarize the present experimental status on kappa-(ET)2Cu2(CN)3 and show unconventional properties (non-Fermi liquidity, quantum criticality, gossamer super-conductivity with BEC nature) in the doped QSL candidate, kappa-(ET)4Hg2.89Br8. For the is-sue of CG, I review the classical glass properties exhibited by a series of theta-ET2X and show that they ,at the same time, exhibit quantum manifestations, which are more apparent with more strongly frustrated lattice; namely, the closer it is to the right triangular lattice.

Wednesday, May 25th, 10:40

Randomness effect on charge glass formation in θ-type BEDT-TTF compounds

Kenichiro HASHIMOTO
University of Tokyo

Charge ordering (CO) is a phenomenon in which electrons in solids crystallize into a periodic pattern of charge-rich and charge-poor sites owing to strong electron correlations. In geometrically frustrated systems, however, a glassy electronic state without long-range CO (the so-called charge-glass state) has been realized. In this talk, I will show that structural defects introduced by x-ray irradiation in θ-(BEDT-TTF)2RbZn(SCN)4 also promote the charge-glass formation. In order to examine the randomness effect on the charge crystallization process, we constructed a time-temperature-transformation (TTT) diagram for the x-ray irradiated samples by using the differential scanning calorimetry (DSC) technique as well as the time evolution measurements of the resistivity. Through the construction of the TTT diagram, we found that with increasing x-ray irradiation time, the charge crystallization time becomes slower and the nose temperature becomes lower. The present findings demonstrate that the randomness effect in addition to the geometrical frustration effect plays an important role in the charge glass formation, which are similar to other glass formation systems such as spin glasses.

Wednesday, May 25th, 11:20

Slow Dynamics in the Charge-Glass Forming Organic Conductors -(BEDT-TTF)2MM'(SCN)4

Tatjana THOMAS
Goethe University Frankfurt

The organic conductors -(ET)2MM'(SCN)4 have become of particular interest due to the development of a non-equilibrium charge-glass (CG) state when the charge-ordering (CO) transition is kinetically avoided by fast cooling [1,2]. In thermal equilibrium, i.e. for slow cooling, CO results from strong onsite and intersite Coulomb interactions. Therefore, the quenched state has been discussed to be a consequence of the geometric frustration of charges on a triangular lattice, which hinders long-range order. This interpretation of a purely electronic mechanism has been currently challenged by the discovery of a structural glass transition in highly frustrated -CsM' with M'=Zn,Co [3], which always exhibit a CG state on experimental time scales.

Fluctuation spectroscopy has proven to be a powerful tool to study the charge carrier dynamics at low frequencies [4], which have shown to become very slow and heterogeneous when approaching the glass transition from above, similar to conventional glass-forming liquids [1,5]. Here, we present extended and systematic noise studies on three compounds MM'=CsCo, RbZn, TlZn with varying degree of frustration in different charge states by using different thermal protocols. From the power spectral density, we extract characteristic energies dominating the resistance noise and compare the results with the quenched states. We will discuss the interplay of charge and lattice dynamics and the observed enhancement of slow fluctuations at the CO phase transition.

[1] Kagawa et al., Nature Physics 9, 419 (2013)
[2] Kagawa and Oike, Adv. Mater. 29, 1601979 (2017)
[3] Thomas/Saito et al., arXiv:2109.00811 (2021)
[4] Müller and Thomas, Crystals 8, 166 (2018)
[5] Sasaki et al., Science 357, 1381 (2017)

Wednesday, May 25th, 12:00

Interplay of charge and spin degrees of freedom in triangular lattice dimerized molecular Mott insulators

Natalia DRICHKO
Johns Hopkins University

Mott insulators are commonly pictured with electrons localized on lattice sites, with their low-energy degrees of freedom involving spins only. Mott insulators based on dimers if BEDT-TTD-type molecules have shown a possibility to additionally host an electric dipole on a dimer lattice site when the charge inversion symmetry on a dimer is broken. It creates a unique situation where electric dipole and spin degree of freedom originate from the same electrons. A static order of electric dipoles can lead to a ferroelectric spin singlet state. Frustrated triangular lattice of dimers of BEDT-TTF and similar molecules can host a spin liquid state, while frustrated lattice of electric dipoles was predicted to produce dipole liquid, where fluctuations of electric dipoles coupled to spins result in a spin liquid state. Using Raman scattering spectroscopy as the main experimental technique, we follow a range of kappa-phase materials based on BEDT-TTF molecule where charge degree of freedom activates and suppresses magnetic excitation spectrum characteristic for triangular lattice S=1/2 antiferromagnets. We observe fluctuating electric dipoles and re-entrant charge order transition for materials close to the transition into ferroelectric state. In the vicinity of the phase border the competing degrees of freedom result in inhomogeneities of the charge fluctuating system, which produces ferromagnetic-like response in magnetic susceptibility.

Wednesday, May 25th, 14:00

Transport in quasi-one dimensional systems

Thierry GIAMARCHI
University of Geneva

Low dimensional systems have peculiar properties quite different from the standard ones of Fermi liquids.

In particular charge and spin degrees of freedom are decoupled which leads to very peculiar consequences for transport properties.

I will discuss these consequences, not only for normal charge and spin transport through such structures, but also for more complicated transport quantities such as the Hall effect. I will also discuss the consequences for experimental systems such as the Bechgaard salts or spin ladders.

Thursday, May 26th, 09:00

Frustrated and Correlated: Metal Insulator Transitions on Triangular Lattices

Antoine GEORGES
Collège de France

I will cover older and newer results on our understanding of the Hubbard model on triangular lattices, with or without a moiré structure, with a particular focus on the transition from a metal to a Mott insulator, and applications to organic materials and transition-metal dichalcogenides bilayers.

Thursday, May 26th, 10:30

Fake Insulators: What are they, and how to spot them?

Louk RADEMAKER
University of Geneva

While the difference between insulators and metals is strictly speaking only defined at zero temperature, it has become commonplace to identify systems with a negative temperature-derivative of the resistivity (drho/dT < 0) as insulators. This is, however, misleading. In particular, sufficiently close to a metal-insulator transition a system can have drho/dT < 0 yet reach a finite zero-temperature resistivity, meaning it is actually a metal. Such 'fake insulators' can obscure the interpretation of Mott- and band metal-insulator transitions. Therefore, we will look into the origin of 'fake insulator'-behavior and the role of disorder and electronic correlations. Finally, we will discuss fake insulators in recent experiments in Moiré systems including twisted bilayer graphene and transition metal dichalcogenide (TMD) bilayers.

Thursday, May 26th, 11:10

Bad metal behavior from slow collective excitations

Simone FRATINI
CNRS

Scattering of charge carriers by slow degrees of freedom can drive an electronic system away from normal transport behavior, causing anomalously large resistivities. At the basis of this phenomenon lies the idea that localization corrections, that are known to make the conductivity vanish in disordered systems, also partially survive when the random environment is dynamical. These quantum corrections are capable of reducing the carrier conductivity below the semiclassical value, provided that the scatterers (phonons or any other collective bosonic excitation) are sufficiently slow.

The above phenomenology, dubbed "transient localization", has been thoroughly studied during the last decade. It has been succesful in explaining the anomalous transport behavior of organic semiconductors, where the role of a dynamical random environment is played by slow molecular vibrations. Because it can cause a large enhancement of the resistivity, transient localization is also a natural candidate to explain bad metal behavior. In particular, it naturally explains the emergence of Displaced Drude Peaks in the optical absorption spectra, as commonly observed in experiments in a variety of materials.

In this talk I shall review recent and ongoing work aimed at applying the concept of transient localization to correlated systems and other bad/strange metals, and discuss likely sources of dynamical disorder that could be at the origin of the phenomenon. I shall also comment on the fact that this whole phenomenon might have been overlooked so far, as it is not captured by popular approaches applied to correlated electron systems, such as Dynamical Mean Field Theory.

[1] Displaced Drude peak and bad metal behavior from the interaction with slow scatterers S. Fratini, S. Ciuchi SciPost Phys. 11, 039 (2021)

[2] Pseudogap metal induced by long-range Coulomb interactions K. Driscoll, A. Ralko, S. Fratini Phys. Rev. B 103, L201106 (2021)

[3] Rise and fall of Landau's quasiparticles while approaching the Mott transition A. Pustogow, Y. Saito, A. Löhle, M. Sanz Alonso, A. Kawamoto, V. Dobrosavljevic, M. Dressel and S. Fratini Nat. Commun. 12, 1571 (2021)

Thursday, May 26th, 11:50

T-square thermal resistivity and quasi-particle hydrodynamics

Kamran BEHNIA
ESPCI Paris

Heat travels in solids thanks to mobile electrons and phonons. Even in a detect-free solid, collisions degrade the flow due to the presence of the lattice. However, there are situations where most collisions for phonons, for electrons or for both conserve momentum. In this hydrodynamic regime, the quasi-particle viscosity plays a significant. Recent studies of thermal transport in a variety of solids such as strontium titanate [1], black phosphorus [2], graphite [3], and antimony [4] reveal a narrow temperature window where normal collisions enhance the heat flow rate. The ubiquitous T-square resistivity of Fermi liquids survives in dilute metals in absence of Umklapp events [5], indicating that it does not require momentum-relaxing collisions. Comparing the available transport data in metals and in normal liquid 3He indicates that energy diffusivity sets the amplitude of T-square thermal resistivitity, while momentum diffusivity (i.e. viscosity) is the driver of T-square electrical resistivitity [6].

[1] V. Martelli et al., Phys. Rev. Lett. 120, 125901 (2018)
[2] Y. Machida et al., Sci. Adv. 4, eaat3374 (2018)
[3] Y. Machida et al., Science 367, 309 (2020)
[4] A. Jaoui, B. Fauqué, K. Behnia, Nat. Commun. 12, 195 (2021)
[5] J. Wang et al., Nat. Commun. 11, 3846 (2020)
[5] K. Behnia, Ann. Phys. 2100588 (2022).

Thursday, May 26th, 13:30

Towards Kitaev Quantum Spin Liquid

Hidenori TAKAGI
MPI for Solid State Research

In conventional magnetic materials, interactions between the spins lead to a phase transition from a high-temperature disordered state to a magnetically ordered state as the temperature is lowered. The transition is typically accompanied by singularities in the thermodynamic observables at the transition point, and spontaneous symmetry breaking and a reduction of the spin entropy to zero as the system enters a unique ground state. However, the spin entropy can also be released without any symmetry breaking, down to zero temperature, by forming a collective quantum spin state with long-range quantum entanglement. This exotic state of matter is called a quantum spin liquid. A goal of condensed matter physics is to discover new quantum phases formed by the ensemble of interacting spins and charges in solids. The QSL is perhaps one of the most exotic quantum phases known so far partly because of the nontrivial elementary excitations and has been attracting the attention of condensed matter scientists for several decades.

In 2006 a theoretical breakthrough in the field of QSLs was reported. Alexei Kitaev proposed a simple new model that is exactly solvable and that gives a QSL ground state, in which the spins fractionalize into emergent quasiparticles — Majorana fermions1. Soon after, a spin-orbital Jeff = 1/2 Mott insulator was identified in a complex 5d iridium oxide. This led to a theoretical proposal for the realization of the Kitaev model using Jeff = 1/2 pseudo-spins in an iridate, and initiated a search for the QSL state and the hidden Majorana fermions in a family of iridium and ruthenium compounds2. I am going to talk about the rapid progress in the materialization Kitaev QSL as well as the hunting of Majorana fermions through the detection of unusual heat transport.

[1] A. Kitaev, Ann. Phys. 321, 2-111 (2006)
[2] H.Takagi, T. Takayama, G. Jackeli, G. Khaliullin, S. E. Nagler, Nat. Rev. Phys. 1, 264–280 (2019)

Thursday, May 26th, 15:00

Quantum spin liquids and superconductivity in honeycomb molecular materials

Jaime MERINO
University of Madrid

Certain organic and organometallic molecular materials, Rb3TT·2H20 and Mo3S7(dmit)3, display a rich interplay of strong correlations, spin frustration, flat bands, spin-orbit coupling and Dirac cone physics. We have considered an effective t-J model on a decorated honeycomb lattice to describe the electronic properties of these molecular crystal layers. At half-filling, numerical analysis of the corresponding S=1/2 Heisenberg model on the decorated honeycomb lattice suggests that the ground state is a quantum spin liquid most likely of the RVB type. Based on RVB theory we find that, under hole doping, superconductivity mediated by short range antiferromagnetic correlations emerges.

Depending on the hole doping s, f and d- wave singlet pairing occurs where f-wave singlet is allowed by the lattice decoration. The superconducting critical temperatures are found to be enhanced with respect to their triangular or square lattice counterparts lacking flat bands.

Thursday, May 26th, 15:40

SU(4) materials: emergence and developments

Masahiko G. YAMADA
Osaka University

There is a lot of interest in finding and identifying novel quantum materials. We here focus on d^1 materials with a strong spin-orbit coupling, which are supposed to realize a much higher symmetry than SU(2), an emergent SU(4) symmetry [1,2].

In fact, alpha-ZrCl3 is expected to host the SU(4) Heisenberg model on the honeycomb lattice with a large frustration [3].

These "SU(4) materials" potentially realize a new type of spin liquids, a gapped Z4 spin liquid [4]. We present new density matrix renormalization group (DMRG) studies on the SU(4) Heisenberg model on the honeycomb lattice to show that the ground state is indeed gapped and symmetric with respect to all the symmetries, indicating the existence of a gapped spin liquid in this system [5].

The topological entanglement entropy is close to the expected value for the Z4 spin liquid, which has 16 superselection sectors in the thermodynamic limit.

Finally, we also indicate a relation to metal-organic frameworks or twisted bilayer graphene on this matter.

[1] M.G.Y., M. Oshikawa, and G. Jackeli, Phys. Rev. Lett. 121, 097201 (2018).
[2] M.G.Y., M. Oshikawa, and G. Jackeli, Phys. Rev. B 104, 224436 (2021).
[3] P. Corboz et al., Phys. Rev. X 2, 041013 (2012).
[4] M.G.Y., and S. Fujimoto, arXiv:2111.14470 (2021).
[5] M.G.Y., K. Penc, and F. Pollmann, to appear.

Thursday, May 26th, 19:30

Higgs Spectroscopy in superconductors

Stefan KAISER
TU Dresden

When a continuous symmetry of a physical system is spontaneously broken, two types of collective modes emerge: the amplitude and phase modes of the order-parameter fluctuation. For superconductors, the amplitude mode is the so called “Higgs mode”, the condensed-matter analogue of a Higgs boson in particle physics. Recent advances in THz technology allow to excite such Higgs modes in superconductors. I will review how this possibility can be extended into a “Higgs Spectroscopy” that reveals the internal structure and dynamics of a superconducting condensate. That becomes in particular interesting for unconventional superconductors where a complicated interplay of competing or intertwined orders obscures the view on the possible pairing mechanism.
I will discuss how a phase resolved nonlinear THz spectroscopy paves the way to such a Higgs spectroscopy directly probing the collective condensate dynamics and exposing its coupling to external collective modes or quasiparticle excitations.

[1] Hao Chu et al., Phase-resolved Higgs response in superconducting cuprates, Nature Commun. 11, 1793 (2020).

[2] Lukas Schwarz et al., Classification and characterization of nonequilibrium Higgs modes in unconventional superconductors, Nature Commun. 11, 287 (2020).

[3] Hao Chu et al., Fano interference of the Higgs mode in cuprate high-Tc superconductors, arXiv:2109.09971

Thursday, May 26th, 20:10

New Physics in Driven Quantum Materials

Andrea CAVALLERI
MPI Structure and Dynamics of Matter

I will discuss how intense and coherent electromagnetic radiation at Tera-Hertz and mid-infrared frequencies can be used to drive complex solids. Collective excitations are driven nonlinearly, leading to coupling amongst otherwise virtually non-interacting normal modes of the material. Driving gives rise to non-thermal states with unconventional properties, and sometimes with emergent order. Interesting examples involve the nonlinear control of the crystal lattice, used to induce magnetic order, ferroelectricity and non-equilibrium superconductivity at high temperatures.

List of Contributions - Talks

Surname	Name	Talk Title
Aeppli	Gabriel	Controlling spins and their interactions in molecular materials
Behnia	Kamran	T-square thermal resistivity and quasi-particle hydrodynamics
Büchler	Hans Peter	Quantum simulation of spin systems with Rydberg atoms
Cavalleri	Andrea	New Physics in Driven Quantum Materials
Drichko	Natalia	Interplay of charge and spin degrees of freedom in triangular lattice dimerized molecular Mott insulators
Fratini	Simone	Bad metal behavior from slow collective excitations
Gati	Elena	Exploring the coupling of Mott insulators to elastic degrees of freedom by pressure tuning
Georges	Antoine	Frustrated and Correlated: Metal Insulator Transitions on Triangular Lattices
Giamarchi	Thierry	Transport in quasi-one dimensional systems
Hashimoto	Kenichiro	Randomness effect on charge glass formation in θ-type BEDT-TTF compounds
Kaiser	Stefan	Higgs Spectroscopy in superconductors
Kanoda	Kazushi	Emergent states of interacting electrons on triangular lattices
Lang	Michael	Probing lattice effects in molecular spin-liquid-candidate systems
Merino	Jaime	Quantum spin liquids and superconductivity in honeycomb molecular materials
Rademaker	Louk	Fake Insulators: What are they, and how to spot them?
Schmalian	Jörg	Strain tuning through critical points
Takagi	Hidenori	Towards Kitaev Quantum Spin Liquid

Surname	Name	Talk Title
Thomas	Tatjana	Slow Dynamics in the Charge-Glass Forming Organic Conductors -(BEDT-TTF)2MM’(SCN)4
Yamada	Masahiko G.	SU(4) materials: emergence and developments

List of Contributions - Poster

Surname	Name	Poster Title
Agarmani	Yassine	Probing charge- and lattice effects around the (presumably Mott) metal-insulator transition in κ -(BETS)2Mn[N(CN)2]3
Biesner	Tobias	Multi-Center Magnon Excitations Open the Entire Brillouin Zone to Terahertz Magnetometry of Quantum Magnets
Ferrari	Francesco	Charge-density waves in kagome-lattice extended Hubbard models at the van Hove filling
Fünfhaus	Axel	Extension of TQC to the Kitaev model
Ganter	Owen	A database for crystalline organic superconductors
Kaib	David A. S.	Magnetoelastic effects in RuCl3
Morgan	Grace	Domain Wall Dynamics in a Ferroelastic Spin Crossover Complex with Giant Magnetoelectric Coupling
Pinar Sole	Andrés	The Nickelocene molecule as an STM Atomic-Spin Sensor
Thyzel	Tim	Noise spectroscopy of Mott criticality and quenched disorder
Zoch	Katharina M.	Kagome quantum spin systems in the atacamite family

09:00
09:30
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Tuesday, May 24th

Registration

Opening Remarks

Jörg SCHMALIAN
Strain tuning through critical points

Gabriel AEPPLI
Controlling spins and their interactions in molecular materials

Hans Peter BÜCHLER
Quantum simulation of spin systems with Rydberg atoms

Coffee Break

Michael LANG
Probing lattice effects in molecular spin-liquid-candidate systems

Elena GATI
Exploring the coupling of Mott insulators to elastic degrees of freedom by pressure tuning

Dinner at Restaurant WASEM

Wednesday, May 25th

Kazushi KANODA
Emergent states of interacting electrons on triangular lattices

Coffee Break and Poster Session

Kenichiro HASHIMOTO
Randomness effect on charge glass formation in θ-type BEDT-TTF compounds

Tatjana THOMAS
Slow Dynamics in the Charge-Glass Forming Organic Conductors - (BEDT-TTF)2MM'(SCN)4

Natalia DRICHKO
Interplay of charge and spin degrees of freedom in triangular lattice dimerized molecular Mott insulators

Lunch Break

Thierry GIAMARCHI
Transport in quasi-one dimensional systems

Poster Flash Presentation

Poster Session

Vineyard Excursion

Jairo's Online Wine Presentation

Dinner at Restaurant WASEM

Thursday, May 26th

Antoing GEORGES
Frustrated and Correlated: Metal Insulator Transitions on Triangular Lattices

Coffee Break and Poster Session

Louk RADEMAKER
Fake Insulators: What are they, and how to spot them?

Simone FRATINI
Bad metal behavior from slow collective excitations

Kamran BEHNIA
T-square thermal resistivity and quasi-particle hydrodynamics

Lunch Break

Hidenori TAKAGI
Towards Kitaev Quantum Spin Liquid

Coffee Break and Poster Session

Jaime MERINO
Quantum spin liquids and superconductivity in honeycomb molecular materials

Masahiko G. YAMADA
SU(4) materials: emergence and developments

Discussion Time and Poster Session

Dinner at Restaurant WASEM

Stefan KAISER
Higgs Spectroscopy in superconductors

Andrea CAVALLERI
New Physics in Driven Quantum Materials

Closing Remarks