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P01

Tunnel Diode Oscillator Studies of Iron-chalcogenide Superconductors

R. M. Abedin[1], **J. S. Pearce**[1], **P. Reiss**[1], **Z. Zajicek** [1], **T. Boutellier**[1], **D. Vignolles**[2], **A. A. Haghighirad**[1,3], **A. I. Coldea**[1]

[1] *Clarendon Laboratory, Department of Physics, University of Oxford, Parks Road, Oxford OX1 3PU, UK*

[2] *LNCMI-EMFL, CNRS UPR3228, Universite Grenoble Alpes, Universite de Toulouse, INSA-T, Toulouse, France*

[3] *Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany*

The exotic high-T_c superconductivity of iron chalcogenides arising from a combination of spin and nematic fluctuations is a very active area of experimental and theoretical investigations [1, 2, 5]. In particular, the high tunability of the different electronic phases by isoelectronic substitution in $FeSe_{1-x}S_x$ and $FeSe_{1-x}Te_x$ allows the study of the superconducting pairing mechanism in different regimes [2, 3]. This is in contrast to Cu substitution in the conducting Fe plane that leads to suppression of both nematicity and superconductivity [5]. Here, we report a tunnel diode oscillator study of $FeSe_{1-x}S_x$ and $FeSe_{1-x}Te_x$ in high magnetic fields up to 80 T. We identify signatures of superconducting and magnetic transitions, which enable us to construct detailed superconducting phase diagrams. Additionally, we follow the evolution of the penetration depth which directly probes the gap structure in FeSe as a function of applied pressure and magnetic fields. Our study reveals the complex nature of high-temperature superconductivity of iron chalcogenides and its unusual interplay with magnetism.

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P02

Origin and stability of generalized Wigner crystallinity in triangular moiré systems

Aman Kumar[1,2], **Cyprian Lewandowski**[1,2], **and Hitesh J. Changlani**[1,2]

[1] *National High Magnetic Field Laboratory, Tallahassee, Florida 32310, USA*
[2] *Department of Physics, Florida State University, Tallahassee, Florida 32306, USA*

Generalized Wigner crystals (GWC) on triangular moiré superlattices, formed from stacking two layers of transition metal chalcogenides, have been recently observed at multiple fractional fillings of the moiré unit cell [Y. Xu et al., Nature 587, 214 - 218 (2020), X. Huang et al. Nat. Phys. 17, 715 - 719 (2021), H. Li et al., Nature 597, 650 - 654 (2021)]. Motivated by these experiments, tied with the need for an accurate microscopic description of these materials, we explore the theoretical origins of GWC at $n = 1/3$ and $2/3$ filling. We demonstrate the general limitations of theoretical descriptions that rely on arbitrarily truncated (finite-range) electron-electron interactions instead of a long-range Coulomb interaction, however, we also clarify why many properties of GWCs at these densities can be captured by an effective nearest-neighbor model. We validate our findings by studying both classical and quantum mechanical effects at zero and finite temperatures. More generally, we discuss the role of charge frustration in the theoretical extended Hubbard-model phase diagram, identifying a “pinball” phase, a partially quantum melted GWC with coexisting solid and liquid-like features, with no classical analog. Quantum effects also explain the small, but experimentally detectable, asymmetry in the transition temperatures of the $n = 1/3$ and $2/3$ crystals. Our calculations reveal that the charge ordering temperature and the magnetic crossover temperature predicted using the long-range Coulomb interaction are adequately captured with appropriately renormalized nearest-neighbor interactions. The effective nearest-neighbor interaction strength is significantly weaker than previously reported, placing the system closer to a metal-insulator phase boundary than may have been anticipated. This observation has implications for future experiments that we discuss. We conclude by studying the dependence of melting temperatures on gate-to-sample separation and we also predict temperature scales at which magnetic crossovers should be observed.

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P03

Mechanisms for Enhanced Superconducting Diode Effect

Sayan Banerjee[1] and Mathias S. Scheurer[1]

[1] *Institute for Theoretical Physics III, University of Stuttgart, 70550 Stuttgart, Germany*

I. ABSTRACT

The superconducting diode effect refers to an asymmetry in critical current of a superconductor in opposite directions. Of particular note is the experiment on twisted trilayer graphene which showed an extreme case of non-reciprocity [1]. While the underlying symmetry constraints for the effect are known, we here propose two distinct mechanisms in order to demonstrate enhancement of non-reciprocity beyond that of conventional theory [2]. First, we demonstrate that a back-action mechanism, in which the supercurrent couples to an underlying time-reversal symmetry-breaking order parameter (valley polarization) [3], can significantly enhance non-reciprocity, though it falls short of explaining the extreme case observed in experiments. To address this, we propose another mechanism [4]that incorporates dissipation effects in the non-equilibrium current-carrying state via phase slips. We show that the coupling of the resistive current to the symmetry-breaking order can also induce a diode effect, with the critical current asymmetry becoming substantial and, in some cases, approaching perfect diode efficiency. The interplay between symmetry-breaking order, superconducting, and resistive currents leads to rich physics, including current-stabilized, non-equilibrium superconducting correlations.

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P04

Floquet-engineering the Hubbard-dimer and plaquette in a strongly interacting electron system

Ulf Behrens Uzin[1], **Silvina Elaskar Cooper**[1], **Andrew J. Millis**[3,4] **and Michael A. Sentef** [1,2]

[1] *Institute for Theoretical Physics and Bremen Center for Computational Materials Science, University of Bremen, 28359 Bremen, Germany*

[2] *Max Planck Institute for the Structure and Dynamics of Matter, Center for Free-Electron Laser Science (CFEL), Luruper Chaussee 149, 22761 Hamburg, Germany*

[3] *Department of Physics, Columbia University, 538 West 120th Street, New York, New York 10027, USA*

[4] *Center for Computational Quantum Physics, Flatiron Institute, 162 5th Avenue, New York, New York 10010, USA*

The interaction between light and matter has always been subject of scientific interest especially in condensed matter physics. With the technology of radiation sources improving[1], it was possible to open up new experimental methods to optically control many body states in form of Floquet-engineering. Floquet-engineering enables the tuning of the Hamiltonian to a desired configuration, thereby opening up a wide range of diverse and potentially immense technological applications for these driven and controlled systems.[2]. A clear manifestation of drive strength effects emerges in the transition of the magnon distribution from subthermal to superthermal in a two-dimensional Hubbard model as the drive strength increases. This has been previously analyzed using a kinetic Boltzmann equation framework[3], and its relevance was initially motivated by microscopic Floquet-Keldysh calculations within mean-field theory [4].
In this work, we focus on the formulation and implementation of Floquet-engineered Hamiltonians in strongly interacting electron systems, with particular emphasis to the driven two-dimensional Hubbard model at half-filling. As a starting point, we consider the Hubbard-dimer and the Hubbard-plaquette. These simple yet effective models will provide insights into the behaviour of a complex Floquet-dissipative non-equilibrium applied to a two-dimensional Hubbard model for a better understanding of the change in magnon distribution.

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P05

Theory of Nonlinear Spectroscopy in Quantum Magnets

Anubhav Srivastava [1,2] , Stefan Birnkammer [1] , GiBaik Sim [3], Michael Knap [1] and Johannes Knolle [1]

[1]*Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany*

[2] *Indian Institute of Science, Bangalore 560012, India*

[3] *Department of Physics, Hanyang University, Seoul 04763, Republic of Korea*

Two-dimensional coherent spectroscopy (2DCS) is an established method for characterizing molecules and has been proposed in the THz regime as a new tool for probing exotic excitations of quantum magnets; however, the precise nature of the coupling between pump field and spin degrees of freedom has remained unclear. Here, we develop a general response theory of 2DCS and show how magneto-electric as well as polarization couplings contribute to 2DCS in addition to the typically assumed magnetization. We propose experimental protocols to distill individual contributions, for instance from exchange-striction or spin current mechanism, when the electric field couples to terms quadratic in spin operators. We provide example calculations for the paradigmatic twisted Kitaev chain material $CoNb_2O_6$ and highlight the crucial role of contributions from cross-coupling between polarization and magnetic nonlinear susceptibilities. Our work paves the way for systematic studies of light-matter couplings in quantum magnets and for establishing 2DCS as a versatile tool for probing fractional excitations of exotic magnetic quantum phases.

P06

Influence of Cavity-Induced Polariton Formation on Superconductivity

Paul Bodewei[1], **Paul Fadler**[2], **and Michael A. Sentef**[1,3]

[1] *Institute for Theoretical Physics, University of Bremen/ Bremen Center for Computational Material Science*

[2] *Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany*

[3] *Max Planck Institute for the Structure and Dynamics of Matter, CFEL, Hamburg*

One of the most exciting directions in modern condensed matter physics is the manipulation of quantum materials using light. In particular, laser-driven control of superconductivity has attracted significant research interest in recent years [1, 2]. However, for greater controllability, cavity systems offer a powerful way to access and manipulate equilibrium quantum properties without the drawbacks of transient optical methods, such as detrimental heating. By tuning parameters such as geometry, light frequency, and coupling strength, one can steer fluctuations to stabilize or even generate entirely new quantum phases, including novel superconducting states. Notably, it has been demonstrated that cavity-induced phonon polaritons can enhance electron-phonon interactions [3], although the potential modification of superconductivity remains an open research question. Interestingly, previous studies have suggested that electron correlations can be influenced by dark cavities due to changes in phonon-mediated attraction [4]. Building on this, we aim to gain further insights into how cavities alter superconductivity. To this end, we focus on charge-transfer κ-salts with strong electronic correlations, which are well described by a Hubbard model. For these materials, it has been shown that laser driving modulates the ratio between the Hubbard interaction U and the hopping t, i.e., U/t, which couples to double occupancies and thus indicates laser-induced superconductivity [2]. Building on this, we aim to investigate how the formation of cavity-induced phonon-polaritons influences the effective interaction ratio U/t, and thereby the superconducting properties of the system.

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P07

Data-Driven Discovery of Novel Quantum Materials Using Graph Neural Networks and Topological Informants

Bariana Bowman [1] , **Jason Gibson** [2] , **Ajinkya Hire** [2] , **Benjamin Geisler** [1,2] , **P. J. Hirschfeld** [1] , **Jiabin Yu**[2,3] **and Richard Hennig**[1,2,3]

[1] *Department of Physics, University of Florida, Gainesville Florida, 32611*
[2] *Department of Materials Science and Engineering, University of Florida, Gainesville Florida, 32611*
[3] *Quantum Theory Project, University of Florida, Gainesville Florida, 32611*

Recent findings, show that the electronic topology can significantly enhance the strength of the electron phonon coupling (EPC), which typically favors superconductivity [1]. This work presents a data-driven approach to accelerate that discovery by integrating symmetry-based topological descriptors with advanced machine learning models. Building on BEENET —an ensemble of bootstrapped, equivariant graph neural networks developed to predict the Eliashberg spectral function—we extend its capabilities to jointly model superconductivity and topological character directly from crystal structures. Using a curated dataset of materials exhibiting both strong electron-phonon coupling and nontrivial topology, we train and benchmark models capable of predicting critical temperature (Tc) and topological indicators. We highlight how domain knowledge, including symmetry indicators and band inversions, enhances model interpretability and performance. This poster shares preliminary screening results, outlines our open-source toolkit for dataset construction and model training, and showcases BEENET's potential in high-throughput discovery pipelines. By leveraging physically meaningful descriptors and scalable ML tools, this project contributes to the development of generalizable, transparent AI frameworks for quantum materials research.

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P08

Interlayer interaction-driven $s_{\pm}$-to-d_{xy}-wave superconductivity in $La_3Ni_2O_7$ under pressure

Lauro B. Braz[1] , **George B. Martins**[2] , **and Luis G. G. de V. D. Da Silva**[1]

[1] *Instituto de Física, Universidade de São Paulo, Rua do Matão 1371, São Paulo, São Paulo 05508-090, Brazil*
[2] *Instituto de Física, Universidade Federal de Uberlândia, Uberlândia, Minas Gerais 38400-902, Brazil*

Experimental and theoretical progress on the normal-state properties of the high-temperature superconductor $La_3Ni_2O_7$ has provided evidence of strong interlayer interactions [1,2]. To better understand the effects of interlayer interactions in $La_3Ni_2O_7$ under high pressure, we investigate a two-layer, two-orbital electron model that includes both intra- and interlayer Coulomb interaction terms within the framework of the matrix random-phase approximation. Our analysis reveals that interlayer interactions play a crucial role in determining the preferred superconducting pairing symmetry. Specifically, when interlayer interactions are included, a d_{xy}-wave pairing symmetry is favored over the $s_{\pm}$-wave symmetry, which was previously found to dominate in their absence [3,4]. Furthermore, we find that interlayer interactions enhance interorbital pairing by incorporating contributions from all three electron pockets, which originate from both $d_{3z^2-r^2}$ and $d_{x^2-y^2}$ orbital characters. This results in the emergence of nodes in the superconducting gap function - features absent in the $s_{\pm}$-wave state - ultimately stabilizing the d_{xy}-wave pairing symmetry.

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P09

High-temperature expansion of dynamical spin correlators: Dyn-HTE

Ruben Burkard,[1] Benedikt Schneider,[2,3] and Björn Sbierski[4]

[1] *Institut für Theoretische Physik, Universität Köln, Zülpicher Straße 77, 50937 Köln, Germany*
[2] *Department of Physics and Arnold Sommerfeld Center for Theoretical Physics, Ludwig-Maximilians-Universität München, Theresienstr. 37, 80333 Munich, Germany*
[3] *Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany*
[4] *Institut für Theoretische Physik, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany*

Currently, there is a scarcity of theoretical methods to calculate dynamical correlation functions at finite temperatures in frustrated spin systems. To address this challenge, we extend the well-established method of high-temperature expansion to the dynamical two-point Matsubara Green's function, which we calculate to high order in perturbation theory. We consider Heisenberg models with one coupling constant J, arbitrary spin length, and without external magnetic field. Moreover, the analytic frequency dependence in the expansion allows for stable analytic continuation to the real-frequency dynamic structure factor after resummation.

P10

Thermal Hall conductivity as a probe of the quasiparticle mean free path in cuprate superconductors

M. Altangerel[1,3], M. Mezidi[1,2], E. Campillo[1], L. Chen[1], A. Vallipuram[1], Q. Barthélemy[1], É. Lefrançois[1], J. Baglo[1], G. Grissonnanche[4], A. Forget[5], D. Colson[5], R. Liang[6], D. A. Bonn[6], W. N. Hardy[6], C. Proust[3], G. Gu[7], L. Taillefer[1]
[1] Institut quantique, Département de physique, Université de Sherbrooke, Sherbrooke, Canada
[2] Université Paris-Cité, Paris, France
[3] Laboratoire National des Champs Magnétiques Intenses, Toulouse, France
[4] École Polytechnique, Paris, France
[5] Université Paris-Saclay, Gif-sur-Yvette, France
[6] Department of Physics and Astronomy, University of British Columbia, Vancouver, Canada
[7] Brookhaven National Laboratory, Upton, New York, USA

The thermal Hall conductivity κ_{xy} can be used to estimate the mean free path of *d*-wave quasiparticles in cuprate superconductors [1]. Here, we report measurements of κ_{xy} in a range of cuprates, including the single-layer $HgBa_2CuO_{6+\delta}$ (Hg1201), the bilayer cuprates $YBa_2Cu_3O_y$ (YBCO) and $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi2212), and the trilayer cuprate $HgBa_2Ca_2Cu_3O_{8+\delta}$ (Hg1223), the superconductor with the highest T_c. We extract the mean free path from our κ_{xy} data and find that Hg1223 exhibits a mean free path as long as that of the cleanest YBCO crystals, suggesting that outer planes play a protective role against disorder. By contrast, Bi2212 has a mean free path approximately ten times shorter than that of YBCO, indicating a much higher degree of disorder. Furthermore, we observe a cubic temperature dependence of the scattering rate in the cleanest superconductors (YBCO and Hg1223), in agreement with theoretical predictions for *d*-wave superconductors [2,3].

Our results highlight the effectiveness of the thermal Hall technique in probing quasiparticle scattering across different cuprate families.

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Jiefu Cen

Intermediate phases in α-$RuCl_3$ under in-plane magnetic field via interlayer spin interactions

α-$RuCl_3$ has attracted significant attention as a prime candidate for the spin-1/2 Kitaev spin liquid in two-dimensional honeycomb lattices. Although its ground state is magnetically ordered, the order is suppressed under a moderate in-plane magnetic field. The intermediate regime of the field has exotic behaviours, some of which are claimed to originate from a Kitaev spin liquid. In resolving debates surrounding these behaviours, the interlayer interactions in α-$RuCl_3$ have been largely overlooked due to their perceived weakness in van der Waals materials. However, near the transition, they may become significant as the field energy approaches the interlayer coupling scale. Here we investigate the effects of interlayer couplings in α-$RuCl_3$ with $R\bar{3}$ and $C2/m$ structures. We first examine their effects on the transition temperature (T_N) using classical Monte Carlo simulations. We found that the interlayer couplings have minimal effects on T_N, and the different T_N between the two structures are mainly due to the anisotropy in the intralayer interactions. Focusing on the $R\bar{3}$ structure, we show that the nearest neighbour interlayer interaction is XXZ-type due to the symmetry, and the next nearest neighbour interaction of the Kitaev-type is crucial for the transition between two zigzag orders under an in-plane field. Furthermore, an intermediate phase with a large unit cell emerges due to the interlayer interactions. Our findings provide new insights into the exotic behaviours and sample dependence reported in α-$RuCl_3$.

P12

Correlation-driven orbital altermagnetism in kagome materials

Anzumaan R. Chakraborty [1] , **Fan Yang** [2] , **Turan Birol** [2], **Rafael M. Fernandes**[1]

[1]*(Presenting author underlined) Anthony J. Leggett Institute for Condensed Matter Theory, University of Illinois Urbana-Champaign, Urbana, 61801, IL, USA*

[2] *School of Physics and Astronomy, University of Minnesota, Minneapolis, 55455, MN, USA*

Altermagnetism describes a broad class of magnetically ordered phases that display zero magnetization, time-reversal symmetry breaking, and nodal d-wave (or higher angular momentum) spin-splitting. While many studies have focused on ordering in the spin degrees of freedom, here we show that metallic kagome-based materials can realize orbital altermagnetism, owing to the existence of van Hove singularities (vHs) in the kagome band structure. Such a state emerges from the interplay of two common instabilities associated with the vHs, namely, bond order and loop-current order. We use a low-energy microscopic model to show that certain combinations of bond and loop-current orders can generate altermagnetism. We propose that the AV3Sb5 kagome metals, which are known to display complex charge-order patterns, are strong candidates to display orbital altermagnetism.

P13

Manipulation of hierarchical zero mode in Dirac superlattice of Jacki-Rebbi zero modes

Subhadeep Chakraborty , **Krishanu Roychowdhury**[2 3 4], **vinash Khare**[5], and **Sourin Das**

Department of Physical Sciences, IISER Kolkata, Mohanpur, West Bengal 741246, India.

[2] *Theory Division, Saha Institute of Nuclear Physics, 1/ F Bidhannagar, Kolkata 700064, India.*

[3] *Homi Bhabha National Institute, Training School Complex, nushaktinagar, Mumbai 400094, India.*

[4] *Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Strasse 38, Dresden 01187, Germany*

[5] *Department of Physics, Savitribai Phule Pune University, Pune 411007, India.*

Superl ttice structures offer promising p thw ys for topologic l b nd engineering. In this work, we demonstr te th t subjecting qu ntum spin H ll insul tor (QSHI) to periodic lly ltern ting exch nge field results in the form tion of Dir c superl ttice composed of J ckiw-Rebbi (JR) modes long the edge. Introducing n ddition l uniform exch nge field induces st ggered hybridiz tion mong these modes, giving rise to Su-Schrieffer-Heeger-J ckiw-Rebbi (SSH-JR) model th t c n host isol ted topologic l minib nds nd robust hier rchic l fr ction l bound ry modes loc lized t the corners of the 2D QSHI. The SSH model is connected to p ir of 1D tight-binding ch ins vi supersymmetric tr nsform tions, with e ch ch in hosting n unp ired edge mode loc lized t one end. These unp ired edge modes c n be m nipul ted by tuning the chemic l potenti l nd pplying tunneling quenches, en bling the cre tion of qu ntum logic g tes, which rem in robust g inst disorder. Tr nsport simul tions r tify our theoretic l predictions [1].

[1] S. Chakraborty, K. Roychowdhury, . Khare, and S. Das, manuscript in preparation.

P14

Disordered topological crystalline phases [1]

Adam Yanis Chaou[1] , **Mateo Moreno-Gonzalez**[2], **Alexander Altland,**[2] **and Piet W. Brouwer**[1]

[1]*Freie Universität Berlin, Dahlem Center for Complex Quantum Systems and Fachbereich Physik, Arnimallee 14, 14195 Berlin*

[2] *Institute for theoretical physics, Universitat zu Koln, Zulpicher Str. 77a, 50937 Cologne, Germany*

The imposition of crystalline symmetries is known to lead to a rich variety of insulating and superconducting topological phases. These include higher-order topological phases and obstructed atomic limits with and without filling anomalies. We here comprehensively classify such topological crystalline phases (TCPs) with mirror, twofold rotation, and inversion symmetries in the presence of disorder that preserves the crystalline symmetry on average. We find that the inclusion of disorder leads to a simplification of the classification in comparison to the clean case. We also find that, while clean TCPs evade a general bulk-boundary principle, disordered TCPs admit a complete bulk-boundary correspondence, according to which (bulk) topological phases are topologically equivalent if and only if they have the same anomalous boundary states and filling anomaly. We corroborate the stability of disordered TCPs by way of field-theoretic, numerical and symmetry-based analyses in various case studies. While the boundary signatures of most disordered TCPs are similar to their clean counterparts, the addition of disorder to certain mirror-symmetric TCPs results in novel higher-order statistical topological phases, in which zero-energy hinge states have critical wavefunction statistics, while remaining protected from Anderson localization.

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P15

Wannier states and spin supersolid physics in the triangular antiferromagnet $K_2Co(SeO_3)_2$

M. Zhu[1], Leandro M. Chinellato[2], V. Romerio[1], N. Murai[3], S. Ohira-Kawamura[3], Christian Balz[4,5], Z. Yan[1], S. Gvasaliya[1], Yasuyuki Kato[6], C. D. Batista[2,7] and A. Zheludev[1]

[1] *Laboratory for Solid State Physics, ETH Zürich, 8093 Zürich, Switzerland*
[2] *Department of Physics, The University of Tennessee, Knoxville, Tennessee 37996, USA*
[3] *J-PARC Center, Japan Atomic Energy Agency, Tokai, Ibaraki 319-1195, Japan*
[4] *ISIS Neutron and Muon Source, STFC Rutherford Appleton Laboratory, Didcot OX11 0QX, United Kingdom*
[5] *Neutron Scattering Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA*
[6] *Department of Applied Physics, University of Fukui, Fukui 910-8507, Japan*
[7] *Quantum Condensed Matter Division and Shull-Wollan Center, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA*

We present a detailed investigation of the spin supersolid phase in the triangular lattice XXZ easy-axis antiferromagnet $K_2Co(SeO_3)_2$, using a combination of ultra-high-resolution inelastic neutron scattering, thermodynamic measurements, and Quantum Monte Carlo numerical simulations. Our study reveals Berezinskii-Kosterlitz-Thouless (BKT) transitions signaling the emergence of Ising and supersolid order, alongside the experimental recovery of Wannier entropy above the supersolid phase [1,2].

At low temperatures and zero field, neutron scattering results show a broad continuum of magnetic excitations, with no discrete coherent magnon modes resolved within an experimental resolution of 23 μeV. A pseudo-Goldstone mode with a small energy gap of 0.06 meV is also detected. In applied magnetic fields, these excitations evolve into coherent spin waves, with distinct behaviors observed in the Goldstone and pseudo-Goldstone sectors.

This work highlights the unique thermodynamics and spin dynamics of the spin supersolid phase, offering quantitative agreement between experimental data and quantum Monte Carlo simulations. The results underscore $K_2Co(SeO_3)_2$ as an ideal platform for exploring supersolid phenomena and the complex interplay of quantum and thermal fluctuations in anisotropic antiferromagnets.

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P16

Integrals of products of Bessel functions: a perspective from the physics of umklapp scattering and the application to transport in twisted bilayer graphene

Joshua M. Covey[1], **Dmitrii L. Maslov**[1]

[1]*Department of Physics, University of Florida, Gainesville, FL 32611-8440, USA*

Integrals of products of Bessel functions exhibit an intriguing feature: they may vanish identically, not due to an orthogonality property, but rather when certain conditions on the parameters specifying the integrand are satisfied. We provide a physical interpretation of this feature in the context of many-body properties of electrons on a lattice ("Bloch electrons"), namely, in terms of the umklapp scattering rate. (In an umklapp event, the change in the momentum of two colliding electrons is equal to a reciprocal lattice vector, which gives rise to a finite resistivity due to electron-electron interaction.) In this context, the vanishing of an integral follows simply from the condition that an umklapp process is kinematically forbidden due to the Fermi surface being smaller than a critical value. Furthermore, we apply these results to transport data for twisted bilayer graphene at small twist angles (but away from the magic angle). We theoretically deduce the temperature scaling behavior for densities above and below the threshold for which umklapp scattering events take place.

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P17

Raman scattering from moiré phonons

Vítor Dantas[1], Héctor Ochoa[2], Rafael M. Fernandes[3] and Natalia B. Perkins[1]

[1] *School of Physics and Astronomy, University of Minnesota, Minneapolis, Minnesota 55455, USA*

[2]*Department of Physics, Columbia University, New York, NY 10027, USA*

[3]*Department of Physics, The Grainger College of Engineering, University of Illinois Urbana-Champaign, Urbana, IL 61801, USA*

Moiré phonons emerge from the interlayer sliding motion in twisted 2D materials and correspond to fluctuations of the stacking order in reconstructed moiré superlattices. These include both gapless phason modes, and a new set of low-energy optical modes [1, 2]. We study the Raman response of moiré phonons in twisted bilayer graphene (TBG), providing a microscopic derivation of the Raman operator based on the symmetry properties of the phonon eigenmodes. Our results reveal a sequence of low-frequency peaks in the Raman intensity of TBG, distinguishing it from the response of decoupled layers. We discuss the influence of anharmonic interactions to the phonon linewidth, and more crucially, the sensitivity of the Raman spectra to both the twisting angle and the incoming light polarization. Our findings establish Raman spectroscopy as a valuable tool to explore the physics of moiré phonons in twisted van der Waals materials.

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P18

Magnetism Driven Topological Phase Transitions in Honeycomb Monolayer Transition Metal Trichlorides

Ritwik Das , Soumen Basak , and Indra Dasgupta

School of Physical Sciences, Indian Association for the Cultivation of Science
2A & B Raja S C Mullick Road, Kolkata 700032, India

Two-dimensional honeycomb ferromagnets offer a promising platform for realizing Chern insulating phases, where the electronic topology can be further tuned by the orientation of magnetic moments through the interplay between spin-orbit coupling and crystal symmetries. First-principles density functional theory (DFT) calculations reveal such tunable topological behavior in the monolayer transition metal trichloride $OsCl_3$ [1], where ligand-induced symmetry breaking and strong spin-orbit interaction enable nontrivial band topology [2]. We further investigate the role of electronic correlations using a model Hamiltonian approach incorporating Hubbard-Kanamori interactions [3]. The resulting correlation-dependent magnetic ground states also exhibit topological phase transitions, suggesting an additional pathway for controlling topological phases through both the electronic band structure and effective spin models. These findings highlight a pathway toward correlation-driven control of topological behavior in two-dimensional quantum materials.

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P19

Kondo effect in strained Kagome ribbons

P.A.Almeida,[2,1] G.B.Martins,[2] and S.E.Ulloa[1]

[1] Department of Physics and Astronomy and Nanoscale and Quantum Phenomena Institute, Ohio University, Athens, Ohio 45701-2979, Brazil
[2] Instituto de Física, Universidade Federal de Uberlândia, Uberlândia, Minas Gerais, 38400-902, Brazil

Kagome systems have received significant attention in recent years, primarily due to the discovery of several Kagome metals, such as AV3Sb5 [1]. These systems present rich physics that can be explored across different branches. Essentially, the Kagome lattice, in a *tight binding* description, is a 2D monolayer that features a unique band structure, combining dispersive bands-like graphene-with a completely flat band in its energy spectrum. This makes it an ideal system for analyzing both topology and correlation effects. Here, we focus on the latter by analyzing the Kondo effect in Kagome nanoribbons under the action of strain. To analyze the model itself, we use the Single Impurity Anderson Model (SIAM) and the numerical renormalization group (NRG). Our results indicate that by manipulating the strain, we can control the suppression or realization of the Kondo effect in our impurity-plus-ribbon system, as well as the size of the Kondo cloud.

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P20

Kondo Breakdown as a Measurement-driven Entanglement Transition

Debraj Debata[1], **Abhirup Mukherjee**[1], **and Siddhartha Lal**[1]

[1]*Indian Institute of Science Education and Research Kolkata (IISER Kolkata)*

A Kondo spin-$\frac{1}{2}$ impurity in local magnetic field shows a $T = 0$ quantum phase transition from the Kondo singlet phase to a field-aligned local moment as the magnetic field strength is tuned. We observe the breakdown of Kondo screening and the destabilization of the entangled singlet state due to tuning the magnetic field close to the critical value. This is a transition from a quantum dynamical state to one with classical dynamics. Fermi liquid excitations lying just above the singlet are replaced by non-Fermi liquid excitations at the QCP. Spectral function and quasiparticle residue also show signatures of Kondo destruction. This system offers a toy model to investigate the decohering effects of an environment on a quantum system against that of a continuous observer. The continuous observer, here modeled by the magnetic field, acts as a form of measurement, generating these remarkable features and driving the system through an entanglement transition.

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P21

Thermodynamics of frustrated quantum Heisenberg antiferromagnets

Oleg Derzhko[1,2]

[1]*Institute for Condensed Matter Physics, National Academy of Sciences of Ukraine, Svientsitskii Street 1, 79011 L'viv, Ukraine*
[2]*Professor Ivan Vakarchuk Department for Theoretical Physics, Ivan Franko National University of L'viv, Drahomanov Street 12, 79005 L'viv, Ukraine*

Frustrated quantum Heisenberg spin systems are a subject of intense ongoing research in the field of magnetism. Although the main focus of these studies is on the ground-state properties of the $S = 1/2$ Heisenberg antiferromagnets, the finite-temperature properties are also of interest. After all, among most common quantities to probe such systems experimentally are the specific heat $c(T)$ or the magnetic susceptibility $\chi(T)$. On the theoretical side, there are not so many methods applicable to tackle the thermodynamics of frustrated quantum spin systems especially in three dimensions. Thus, quantum Monte Carlo suffers from the sign problem, exact diagonalization or finite-temperature Lanczos methods are restricted to too small lattices, whereas the density-matrix renormalization group technique requires a mapping via a "snake" path to a one-dimensional system.

The aim of our present study is to examine the finite-temperature properties of the $S = 1/2$ Heisenberg antiferromagnet on the pyrochlore lattice [1] and the hyperkagome lattice [2]. To this end, we use the high-temperature series expansions [3, 4] complemented with the entropy-method interpolation [5, 6, 7]. Besides, we determine the temperature dependencies of c and χ numerically for periodic lattices of several unit cells. Among our most interesting findings is an additional low-temperature feature of the specific heat such as peak or shoulder which indicates a hidden energy scale in the system at hand [8]. We also examine the ferromagnetic counterpart of geometrically frustrated quantum spin systems: Since the low-energy levels for the antiferromagnet are the high-energy levels for the ferromagnet, they may manifest themselves in finite-temperature thermodynamics, when due to thermal fluctuations they can come into play [9].

This talk is based on the ongoing research in collaboration with Taras Hutak (L'viv), Taras Krokhmalskii (L'viv), Maksym Parymuda (L'viv), Johannes Richter (Magdeburg), and Jürgen Schnack (Bielefeld). The project is funded by the National Research Foundation of Ukraine (2023.03/0063, Frustrated quantum magnets under various external conditions).

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P22

A New look on an old problem: mass enhancement in Fermi liquids

A.Yu. Efimova[1], **and L. Rademaker**[1]

[1]*University of Gerneva*

In this work, we explore the relationship between the mass enhancement and specific heat in Fermi liquids by bridging the gap between the microscopic theory of interacting electrons and the phenomenological framework of Landau's Fermi liquid theory.
This is done by studying the role of electron self-energy in renormalising quasiparticle effective mass.There exist two distinct mechanisms for mass enhancement: the frequency-dependent quasiparticle weight reduction (ω- mass) and momentum-dependent self-energy effects (k-mass). These two contributions affect the density of states and specific heat differently, leading to discrepancies with traditional Landau theory. However, we demonstrate that these differences can be compensated by the temperature dependence of the self-energy, restoring consistency with Landau's predictions under certain conditions. This gives rise to a new sum rule connecting the Sommerfeld specific heat coefficient to a functional of energy density, verified through numerical simulations on the Bethe and triangular lattice Hubbard model using Dynamical Mean Field Theory (DMFT).

Effects of Disorder and Environmental Noise on Parity Symmetry Breaking in Quantum Spin Systems

B. El Alaoui[1] , A. Slaoui[1,2] , and R. Ahl Laamara[1,2]

[1]LPHE-Modeling and Simulation, Faculty of Sciences, Mohammed V University in Rabat, Rabat, Morocco.

[2] Centre of Physics and Mathematics, CPM, Faculty of Sciences, Mohammed V University in Rabat, Rabat, Morocco.

Abstract. The interplay between disorder and environmental noise plays a crucial role in shaping the quantum properties of spin systems. In this context, we investigate the relationship between the Wigner function and Wigner-Yanase skew information, which are linked through quantum coherence. States exhibiting high skew information tend to develop pronounced negative regions in their Wigner functions, reflecting quantum interference and non-classical behavior. By leveraging this connection, we analyze the effects of parity symmetry and asymmetry in superpositions of spin coherent states, both for spin-1/2 and general spin-j. Our results indicate that the violation of parity symmetry, or the persistence of parity asymmetry, becomes more pronounced as the spin value j increases. Furthermore, we explore how these symmetry properties evolve when the system is subjected to a Gaussian noise channel, modeling the impact of environmental decoherence. Specifically, we examine the critical points where parity symmetry is broken in the spin-1/2 cat state and analyze how this effect intensifies with increasing decoherence parameters. Our findings highlight the fundamental role of spin-j in the robustness of parity asymmetry under noise, offering insights into the influence of disorder and external perturbations in quantum spin systems.

P24

Low-energy magnetic models for the Floquet-dissipative Hubbard model

S. Elaskar Cooper [1], **U. Behrens** [1], **M. Claassen** [3,5], **A. J. Millis** [4,5] **and M. A. Sentef** [1,2]

[1] *Institute for Theoretical Physics and Bremen Center for Computational Materials Science, University of Bremen, Bremen, Germany*
[2] *Max Planck Institute for the Structure and Dynamics of Matter, Center for Free-Electron Laser Science (CFEL), Luruper Chaussee 149, Hamburg, Germany*
[3] *Department of Physics and Astronomy, University of Pennsylvania, Philadelphia, USA*
[4] *Department of Physics, Columbia University, New York, NY 10027, USA*
[5] *Center for Computational Quantum Physics, Flatiron Institute, 162 5th Avenue, New York, New York 10010, USA*

Functionalization of materials through light-matter coupling is one of the major research focuses of modern condensed matter physics. In order to understand how driving with lasers [1] or coupling to cavities [2] can change magnetic and/or topological phases [3], it is necessary to further develop theoretical modeling both with analytical tools and numerical simulations.
A promising strategy for light-matter control of magnetic systems is Floquet engineering of the electronic Hamiltonian through laser excitation, with laser frequency detuned from electronic transitions to avoid heating [3,4]. However, in the presence of dissipation, i.e., when the system is coupled to a bath, the Floquet-engineered magnetic low-energy Hamiltonian will generally not be in a thermal state. While challenging, this also opens new opportunities for creating nonthermal phases that might be inaccessible in equilibrium.

Here we will present steps towards a description of Floquet-dissipative non-equilibrium steady states in the two-dimensional Hubbard model, studied before in an effective Boltzmann kinetic equation with magnon-magnon interactions [5] for a model motivated from microscopic Floquet-Keldysh calculations within mean-field theory plus one-loop corrections [6]. Specifically we will show strong-coupling perturbative expansions for an optically driven half-filled 2D square-lattice Hubbard model coupled to an infinite bandwidth dissipative reservoir, together with numerical analysis using exact diagonalization of finite clusters. A discussion of the relevance of our results to existing and potential future experiments in the field will be provided.

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P25

Topological Phases And Edge States In An Exactly Solvable 1D Quantum Γ Matrix Model

Akhil Pravin Furtado[1] , Dr Kusum Dhochak [1,2]

[1,2] *Department of Physics, Indian Institute of Technology Palakkad*

We study the topological phases and phase transitions of a 1D quantum many-body model with Γ matrix degrees of freedom. The Γ matrices facilitate multiple competing couplings, thereby increasing the parameter space and resulting in a more intricate phase diagram with distinct topological phases. The model is exactly solvable with a generalized Jordan Wigner Transformation. We study the phase diagram of the model. Using certain Z2 symmetries, we characterize the topological phases with the winding number. We also confirm the presence of Majorana Zero energy Edge states by diagonalizing the real space Hamiltonian. Additionally, we examine the critical behaviour with the universality classes of the various phase transitions.

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P26

Butterflies Beyond Hofstadter: Realistic Spectra for Lattice Electrons in a Large Field

Ivo A. Gabrovski[1], **Louk Rademaker**[1,2]

[1] *University of Geneva*
[2] *Leiden University*

The Hofstadter model is a hallmark model, which considers a tight-binding Hamiltonian on a square lattice with a large out-of-plane magnetic field, and produces very visually appealing fractal and periodic in magnetic flux spectra [1]. However, it is a toy model that will never be realized in real materials due to crude assumptions such as the validity of the Peierls substitution and the independence of electronic orbitals from magnetic field. The question of charged particles in a large magnetic field and periodic potential is much more general and leads to much richer physics, which is never reducible to a simple Hofstadter model. For example, we can confidently say that the TKNN model, consisting of electrons in a two-dimensional cosine potential and a large magnetic field [2], undergoes topological phase transitions at given magnetic flux strengths upon an increase of the periodic potential strength, instead of reducing to a Hofstadter model as originally thought [3]. In this work, we calculate the spectrum, topological properties, and charge localization of the TKNN model in the weak potential limit using exact diagonalization in a Landau level basis. In the tight-binding limit, we show how the Peierls substitution can be extended beyond nearest-neighbour hopping and compare this two limits. We also discuss the validity of the Peierls substitution in real systems.

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Quasiparticle Interference in Charge Density Wave Phase Of $2H-NbSe_2$

R Gholap[1], **B Gavan**[1], **and S Bahramy** [1]

[1] *School of Physics and Astronomy, University of Manchester.*

Charge density waves (CDWs) are fascinating quantum phenomena that affect various physical properties of their host. CDWs in pristine $2H-NbSe_2$ have been a topic of intense research. In the CDW phase, numerous scanning tunnelling microscopy (STM) probes1 confirm the localization of the electron density of states (LDOS). In this work, we use an impurity scattering model to achieve similar LDOS patterns as observed in STM experiments. We further use this model to show that QPI caused by inter-K pocket transitions, led by a skew scattering mechanism, is responsible for the features seen in STM probes. We also show that acoustic phonon modes emanating from in-plane Nb orbitals and out-of plane Nb orbitals $4d_{x^2-y^2}, 4d_{xy}4d_{z^2}$, are most likely responsible for the occurrence of CDW features.

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P28

Local Signatures of Altermagnetism and Interplay with Superconductivity

Jannik Gondolf[1], **Andreas Kreisel**[1], **Mercè Roig**[1,2], **Yue Yu**[2], **Daniel F. Agterberg**[2] **and Brian M. Andersen**[1]

[1]*Niels Bohr Institute, University of Copenhagen, DK-2200 Copenhagen, Denmark*
[2]*Department of Physics, University of Wisconsin–Milwaukee, Milwaukee, Wisconsin 53201, USA*

Altermagnets constitute a class of collinear compensated Néel ordered magnets that break time-reversal symmetry and feature spin-split band structures even in the absence of relativistic spin-orbit coupling [1, 2]. This distinction can originate from anisotropic local crystal environments around the different sublattice sites. Based on versatile microscopic models able to capture the altermagnetic sublattice degrees of freedom, we study characteristic local signatures of altermagnetism near disorder sites [3]. We give a complete list of two-dimensional models that exhibit altermagnetism classified by their corresponding layer groups. Specifically, we calculate the local density of states in the vicinity of pointlike nonmagnetic impurities and expose its spatial dependence for two minimal models showcasing d-wave and g-wave altermagnetism. The momentum structure of the nodes (d-wave, g-wave, etc.) is directly imprinted on the total local density of states, thus measurable by scanning tunneling conductance experiments. This signature is present both in the spin-resolved as well as the spin-summed local density of states. We find a weaker response in the nonmagnetic state from the anisotropic crystal environment and uncover the importance of the sublattice degree of freedom to model altermagnets. We also study coexistence phases of altermagnetism and superconductivity and provide predictions for the local impurity response of in-gap bound states. The response of impurity bound states strongly enhances the distinct altermagnetic signature.

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P29

Reflections of topological properties in the planar-Hall response for semimetals carrying pseudospin-1 quantum numbers

Firdous Haidar, and Ipsita Mandal

Department of Physics, Shiv Nadar Institution of Eminence (SNIoE), Gautam Buddha Nagar, Uttar Pradesh 201314, India

We continue our investigations of the nature of the linear-response tensors in planar-Hall and planar-thermal Hall configurations, involving three-dimensional nodal-point semimetals, by considering here nodes hosting pseudospin-1 quasiparticles. Such systems exemplify multifold semimetals, as they have three bands crossing at a nodal point. We derive the explicit expressions of the electric, thermoelectric, and thermal coefficients, when the nodes are subjected to the combined influence of an electric field (and/or temperature gradient) and a weak (i.e., nonquantizing) magnetic field. In order to have a complete description, we consider the effects of the Berry curvature and the orbital magnetic moment on an equal footing, both of which originate from the underlying topological features of the bandstructure. Going beyond our previous works, we determine the out-of-plane response comprising the intrinsic anomalous-Hall and the Lorentz-force-contributed currents, and chalk out the effects of internode scatterings as well. Our theoretical explorations shed light on the mechanisms of transport in multifold semimetals, which are being investigated in contemporary experiments.

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P30

Obstructed pairs – a strong-coupling pairing mechanism with zero superfluid stiffness

Tamaghna Hazra[1] **and Jörg Schmalian**[1,2]

[1] *Institute of Condensed Matter Theory, Karlsruhe Institute of Technology, Karlsruhe 76131, Germany*

[2] *Institute of Quantum Materials and Technology, Karlsruhe Institute of Technology, Karlsruhe 76131, Germany*

We present a microscopic pairing mechanism in which the kinetic energy of pairs is much lower than the kinetic energy of electrons. This results in interaction-driven localization of charge without extrinsic disorder and is characterized by a vanishing superfluid stiffness. Localized pairs gain more kinetic energy from resonating between sublattices in a bosonic compact localized state, than from delocalizing throughout the material. This is grounded in a microscopic model building on a structural motif shared by many oxide superconductors strongly interacting localized electrons realize spin degrees of freedom on the vertices and doped charge lives on the edges of the Bravais lattice. In the strong-coupling limit, local unconventional pairs realize the bosonic analog of flat bands supported on line graphs. We discuss the experimental implications of this pairing mechanism, with concrete falsifiability criteria, and emphasize the broad scope of this recipe in connection to diverse families of strongly correlated materials which share the key ingredients that go into it.

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P31

The Current Boundaries of Unconventional Superconductivity Computations

G Heier[1] **and S Savrasov**[1]

[1] *University of California, Davis*

Spin fluctuations have been proposed as a key mechanism for mediating superconductivity, particularly in high-temperature superconducting cuprates, where conventional electron-phonon interactions alone cannot account for the observed critical temperatures. Traditionally, their role has been analyzed through tight-binding-based model Hamiltonians. In this work we present a method that combines density functional theory with a momentum- and frequency-dependent pairing interaction derived from the fluctuation exchange (FLEX) type random-phase approximation (FLEX-RPA) to compute Eliashberg spectral functions $\alpha^2F(\omega)$, which are central to the spin-fluctuation theory of superconductivity. We apply our numerical procedure to study a series of cuprates where our extracted material-specific $\alpha^2F(\omega)$ are found to exhibit remarkable similarities characterized by a sharp peak in the vicinity of 40–60 meV and their rapid decay at higher frequencies. Our exact diagonalization of a linearized BCS gap equation extracts superconducting energy-gap functions for realistic Fermi surfaces of the cuprates and predicts their symmetry to be $d_{x^2-y^2}$ in all studied systems. Via a variation of onsite Coulomb repulsion U for the copper d electrons we show that the range of the experimental values of T_c can be reproduced in this approach but is extremely sensitive to the proximity of the spin-density wave instability. These data highlight challenges in building first-principle theories of high-temperature superconductivity but offer new insights beyond previous treatments, such as the confirmation of the usability of approximate BCS-like T_c equations, together with the evaluations of the material-specific coupling constant λ without reliance on tight-binding approximations of their electronic structures.

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P32

A gapless 1D spin liquid as a critical point between fragile Kondo insulators

Nai Chao Hu[1]

[1] *Department of Physics and Astronomy, Ghent University, Krijgslaan 281, S9, 9000 Gent, Belgium*

Kondo insulators acquire their incompressible character via a spin exchange coupling between itinerant charge carriers and local moments. Motivated by recent advances in tunable moiré materials, we focus on a class of Kondo insulator models where both the bandwidth and the quantum geometry of the itinerant electrons can be tuned. We show that already in the simplest such model interesting physics arises. In particular, we show evidence that in a 1D model tuning the kinetic energy of the itinerant electrons drives a second-order phase transition where the critical fluctuations are carried by the spin degrees of freedom. Moreover, the transition falls outside the usual Landau paradigm for symmetry-breaking transitions, and has connections to generalized Lieb-Schultz-Mattis obstructions.

P33

Multipole orders and quantum spin liquids in spin-$3/2$ honeycomb models

Sogen Ikegami[1], **Kiyu Fukui**[1,2], **Rico Pohle**[3], **and Yukitoshi Motome**[1]

[1]*Department of Applied Physics, The University of Tokyo*
[2]*Department of Physical Sciences, Ritsumeikan University*
[3]*Creative Science Unit, Shizuoka University*

Quantum spin liquids have been extensively studied in $S = 1/2$ systems due to their remarkable properties such as the absence of magnetic order, fractionalized excitations, and topological order [1, 2, 3]. Extending beyond $S = 1/2$ systems, magnets with $S \geq 1$ introduce additional multipolar degrees of freedom, offering the potential for a rich variety of both ordered and disordered states with multipolar character [4]. Indeed, in $S = 1$ systems with quadrupolar degrees of freedom, diverse quantum states have been realized in models with bilinear, biquadratic, and anistropic interactions [5]. On the other hand, $S = 3/2$ systems additionally possess octupolar degrees of freedom (Fig. 1) and can host the Kitaev spin liquid [6, 7] and the Affleck-Kennedy-Lieb-Tasaki (AKLT) state [8, 9] on a honeycomb lattice (Fig. 2), suggesting the potential for much richer quantum phenomena. However, the effect of the biquadratic and bicubic interactions in $S = 3/2$ systems has not been fully clarified so far, and the interplay between quantum spin liquids and multipole orders remains elusive.

In this study, we investigate the ground states of two different $S = 3/2$ quantum spin models on a honeycomb lattice. One is the "b^3 model" with isotropic bilinear, biquadratic, and bicubic interactions, and the other is the Kitaev-AKLT model, which is a combination of two exactly solvable models that stabilize quantum spin liquid ground states. Using a semiclassical approach based on SU(4) spin coherent states, we show that the b^3 model exhibits multipolar ordered phases with suppressed magnetic dipole moments and that the Kitaev-AKLT model exhibits various dipolar ordered phases, including noncoplanar multiple-Q states. We will also discuss the effects of nonlocal quantum effects beyond the semiclassical approach.

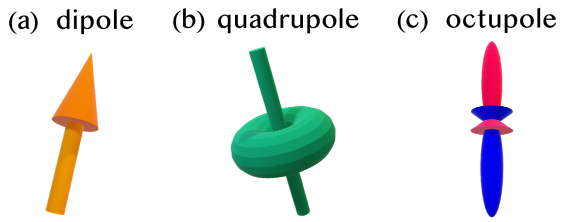

Figure 1: Schematic pictures of magnetic multipoles associated with spin $S = 3/2$.

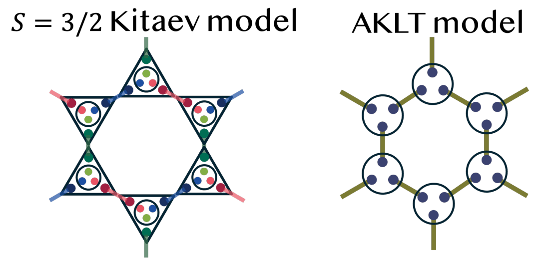

Figure 2: Schematics of the $S = 3/2$ Kitaev model and the AKLT model.

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P34

Pressure-dependent magnetism of the Kitaev candidate Li_2RhO_3

Efrain Insuasti[1], **Bin Shen**[2], **Ramesh Dhakal**[3], **Friedrich Freund**[2], **Philipp Gegenwart**[2], **Steve M. Winter**[3], **and Alexander A. Tsirlin**[1]

[1] *Félix Bloch Institute for Solid State Physics, University of Leipzig, Germany*
[2] *Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg, Germany*
[3] *Wake Forest University, USA*

In the search for a Quantum Spin Liquid (QSL) state in real materials[1], hydrostatic pressure is employed to move honeycomb Kitaev compounds closer to or farther from a QSL state. The candidates studied so far have exhibited long range magnetic ordering at lower temperatures. However, the candidate Li_2RhO_3 [1] does not show a magnetic transition at low temperatures but instead exhibits spin freezing. Magnetic couplings obtained through theoretical super-exchange and Exact Diagonalization calculations [3, 4] evolve away from the Kitaev limit as pressure increases. Interestingly, the freezing temperature determined in our magnetization measurements remains constant under increasing pressure and does not correlate with the changes in magnetic couplings. An analysis of simulations and experiments suggests that spin freezing could arise from extrinsic factors such as stacking faults and crystal defects. Furthermore, the J_3 coupling was found to be unusually small in comparison with other Kitaev materials. Our work shows commonalities in the pressure evolution of the Kitaev iridates and rhodates where the decrease in the bond angle suppresses the Kitaev coupling while enhancing the off-diagonal anisotropy. This work was supported by DFG via TRR360 (492547816) subproject B3.

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P35

Boltzmann Transport in the Strange Metal Phase of Electron-Doped Cuprates

C. Iorio-Duval [1,2], **L. Chen** [3], **A. Ataei** [1], **O. Gingras** [4], **K. Xu** [5], **Z.X. Shen** [5], **S. Ghotb** [1], **G. Hardy** [1], **P. Fournier** [1], **J. Baglo** [1], **G. Grissonnanche** [2], **and L. Taillefer** [1]

[1] *Institut quantique, Département de physique and RQMP, Université de Sherbrooke, Sherbrooke, Quebec, Canada.*

[2] *Laboratoire des Solides Irradiés, CEA/ DRF/lRAMIS, CNRS, École Polytechnique, Institut Polytechnique de Paris, Palaiseau, France.*

[3] *Department of Physics, University of California, Berkeley, Berkeley, CA 94720, USA.*

[4] *Center for Computational Quantum Physics, Flatiron Institute, New York 10010, USA.*

[5] *Departments of Physics and Applied Physics, Stanford University, Stanford, California, USA*

In a previous study of the hole-doped cuprate Nd-LSCO, angle-dependent magnetoresistance (ADMR) data were accurately described by Boltzmann transport, revealing new features of the Fermi surface and the scattering rate. It was discovered that the inelastic scattering rate in the strange metal regime, just above the pseudogap critical doping p*, has a Planckian isotropic value [1]. It was also observed that the Fermi surface undergoes a major transformation upon entering the pseudogap phase by lowering the doping below p* [2]. Our goal is to investigate the Fermi surface and the scattering rate in the electron-doped cuprates $Nd_{2-x}Ce_xCuO_4$ (NCCO) and $Pr_{2-x}Ce_xCuO_4$ (PCCO). Two studies were conducted in magnetic fields up to 42 T at the National High Magnetic Field Laboratory in Tallahassee: 1) ADMR measurements on a NCCO single crystal with x = 0.17 and 2) Hall effect measurements on PCCO thin films with x = 0.15 and x = 0.18. We present those data and their analysis in terms of Boltzmann calculations.

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P36

Probing topological Floquet states in graphene with ultrafast THz STM

N. Jacobsen [1,2], **M. Müller** [3], **M. Schüler** [4,5], **M. Wolf** [3], **A. Rubio** [2,6], **M. A. Sentef** [1,2]

1 ITP, University of Bremen, Bremen, Germany
2. Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany
3. Fritz Haber Institute of the Max Planck Society, Berlin, Germany
4. Laboratory for Materials Simulations, Paul Scherrer Institut, Villigen, Switzerland
5. Department of Physics, University of Fribourg, Fribourg, Switzerland
6. Center for Computational Quantum Physics The Flatiron Institute, New York, USA

Floquet band engineering enables control of solid-state systems via periodic laser driving. The light-induced anomalous Hall effect in graphene under circularly polarized light [1] has been observed in ultrafast transport measurements [2], and more recently, Floquet replica bands induced by linearly polarized light have been reported using time-resolved photoemission spectroscopy [3]. Here, we propose probing topological Floquet states in graphene using ultrafast scanning tunneling microscopy (THz STM) as a complementary experimental technique [4].

Specifically, we present Keldysh Green's function simulations of the THz STM signal for Floquet-driven graphene. We analyze signatures of light-induced gap openings and the formation of topological edge states, focusing on their imprints in the THz STM response. We further investigate how these signatures depend on key experimental tuning parameters—namely, the pump frequency (ranging from near-infrared to optical) and light polarization (linear vs. circular). Finally, we explore the potential of imaging the topological nature of Floquet states by analyzing their quasiparticle interference (Floquet-QPI) patterns. Our findings highlight ultrafast STM as a versatile and promising tool for probing light-induced topological states in quantum materials.

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P37

The demonstration of tunable correlated insulators, superconductors and magnetism in twisted sheets of graphene has revolutionized condensed matter physics, both theory and experiment.
The twisting of two sheets of graphene folds the electronic structure and creates narrow low energy bands, promoting instabilities for correlated states to emerge. However, as graphene lacks (significant) spin-orbit coupling, spin and topology-related effects are strongly suppressed.
I will present theoretical studies of a new class of exfoliable, stackable and twistable materials in group 14: silicene, germanene, and stanene (tin). Building on first-principle calculation and continuum models, I will present the abundance of topological, magnetic and superconducting instabilities in systems of few layer Xenes (X=Si,Ge,Sn), with rhombohedral stacking. Due to the inherent buckling and orbital mixing of pz and px,py orbitals, Xene multilayers have superior response to vertical displacement fields. I will present accurate tight-binding models for the effective description of interaction effects, including electrostatic doping and gates. Finally, I will show that multilayer stacks of Xenes allow for higher-order van Hove singularities with unique orbital textures and strong effects from spin-orbit coupling.
My results will highlight the possibilities opened up by pristine, tunable, interacting and spin-orbit dominated layered materials, ushering in the next stage of the materials revolution enabled by graphene.

P38

Conductivity of composite pairs of fermions in anticorrelated disorder

Lolita I. Knyazeva [1,2] , **Vladimir I. Yudson** [3,1]

[1] *Russian Quantum Center, Skolkovo, Moscow 143025, Russia*
[2] *Moscow Institute of Physics and Technology, Dolgoprudny 141700, Russia*
[3] *Laboratory for Condensed Matter Physics, HSE University, Moscow, 101000 Russia*

The problem of interplay of interaction between particles and disordered external potential is one of the most important issues of condensed matter physics. Within this work, we study a two-component fermionic system with interspecies attractive interaction on a lattice with anticorrelated disorder. If particles of different species occupy the same site, they can form bound pairs. And the locality of this interaction leads to the suppression of disorder for these composite pairs. As a result, the pair transport becomes possible, while for separate subsystems Anderson localization takes place. In our study we go to the effective Hamiltonian of composite pairs and describe their transport at high temperatures ($T_{degeneracy} \ll T$) with the use of the Boltzmann equation. It turns out that, as long as the temperature is less than the band energy, the temperature dependence is different for space dimensions $d = 2$ and $d = 3$. But at higher temperatures it does not depend on the space dimension and is determined by both the disorder potential and the interaction between the composite pairs.

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P39

Symmetry Study of Elemental Rhenium

Márk Kondákor[1,2], **Karlo Penc**[2]

[1] *Institute of Physics, Budapest University of Technology and Economics, Hungary*
[2] *2HUN-REN Wigner Research Centre for Physics, Budapest, Hungary*

Recent muon spin rotation (μSR) experiments on elementary rhenium have shown that its superconducting phase spontaneously breaks time-reversal symmetry [1]. Ab initio calculations further indicate that finite magnetic moments of opposite directions arise on the two atoms in the crystal's elementary cell, coexisting with the superconducting state [2]. The observed activated specific heat can be accounted for by a mixture of spin-singlet and spin-triplet Cooper pairs.

To elucidate these findings, we performed a comprehensive symmetry classification of all possible superconducting and magnetic order parameters in the nonsymmorphic crystal structure of rhenium.We employed double-group theory to classify the spin-orbit coupled electronic states. We identified the relevant symmetry channels for time-reversal symmetry breaking and determined the corresponding terms in effective interaction. Our results shed light on the interplay between spin and orbital degrees of freedom in rhenium and provide a theoretical framework for exploring magnetism and superconductivity in other nonsymmorphic materials.

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P40

Density of scattering resonances in a disordered system

M. S. Kurilov[1,2,3,4]**, P. M. Ostrovsky**[5]

[1] *Nanocenter CENN, Ljubljana, Slovenia*
[2] *Department of Physics, University of Ljubljana, Slovenia*
[3] *L. D. Landau Institute for Theoretical Physics, Chernogolovka 142432, Russia*
[4] *Moscow Institute of Physics and Technology, Dolgoprudny, Russia*
[5] *Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany*

The system under study consists of a disordered system and an M-channel ballistic lead connected to it. The reflection of waves incident on the disordered part is described by the S matrix. We are interested in the statistics of resonance widths (i.e., imaginary parts of the poles of the S matrix). Using the framework of a supersymmetric nonlinear sigma model we derive general formulas of the resonance widths distribution for all three Wigner-Dyson classes and calculate it in the zero-dimensional limit for the case of identical transmission coefficients. Obtained formulas are in a good agreement with numerical RMT simulations.

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P41

Ordered states near ordinary and higher-order Van Hove points in graphene systems

Yueh-Chen Lee [1] , **Dmitry V. Chichinadze** [2] , **and Andrey V. Chubukov** [1]

[1] *School of Physics and Astronomy, University of Minnesota*
[2] *National High-Magnetic Field Laboratory, Florida*

We study the crossover from ordinary van Hove singularity (oVHP) to higher order van Hove singularity (hoVHP) in a model used for Bernal bilayer graphene and rhombohedral trilayer graphene. Low energy states in these systems are located near K and K' points on the hexagonal lattice. Under density variation, the electronic structure undergoes a topological van Hove transition from three disconnected Fermi surfaces to a single Fermi surface via either three separate oVHP or a single hoVHP. We model this behavior by introducing a parameter, which allows us to interpolate between oVHP and hoVHP. Our goal is to analyze how the set of potential ordered states changes between oVHP and hoVHP. We apply a parquet remornalization group (RG) analysis to detect the leading instabilities in the particle-hole and particle-particle channels. We find that there is a substantial evolution of the ordered state between oVHP and hoVHP. The evolution includes disappearance/reemergence and pair production/annihilation of the fixed points of RG trajectories.

P42

Topology-driven deconfined quantum criticality in magnetic bilayers

Sondre Duna Lundemo[1], **Flavio S. Nogueira** [2], **and Asle Sudbø**[1]

[1] *Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway*

[2] *Institute for Theoretical Solid State Physics, IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany*

Two-dimensional quantum antiferromagnets are believed to host phases of matter whose excitations are more fundamental than those of the ordered phases. When combining two such spin systems in a bilayer, strong interaction between the emergent excitations can produce phases not realized in either of its subsystems. We show that the critical fluctuations of a two-dimensional spin liquid state can induce a deconfined quantum critical point in a proximate antiferromagnet. The most relevant coupling between the associated effective field theories is given by a mixed Chern-Simons term of the emergent gauge fields in each layer. This describes a topological current-current interaction. In contrast to the local spin-spin interaction, it strongly modifies the renormalization group flow of the theory describing the Néel–valence-bond-solid transition of the antiferromagnet. In particular, the protected coupling constant associated with it implies non-trivial quantum critical scaling characterized by a non-universal power-law divergence of the correlation length in the critical domain and Berezinskii–Kosterlitz–Thouless divergence approaching it.

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P43

Emergence of chiral edge states and coulomb correlation effects in time-reversal symmetry broken MXenes

Kishan H. Mali[1*], **and Alpa Dashora**[1]

[1] *Department of Physics, Faculty of Science, The M.S. University of Baroda, Vadodara, 390002, India*

Broken time-reversal symmetry (TRS) and spin-orbit coupling (SOC)-assisted non-trivial band topology are the prerequisites to achieve a superior quantum state of matter with a non-zero Chern number. Further, observation of Chern insulators, axion insulators, and the quantum anomalous Hall (QAH) effect in intrinsic magnetic materials with non-trivial band topology are exceptionally rare and challenging. While the two-dimensional (2D) family of $MnBi_2Te_4$ [1] has provided some exploration in this area, the material subset exhibiting these coexisting properties remains significantly smaller compared to the broader category of topological insulators. MXenes belong to a class of 2D systems that could be utilized in the field of spintronics due to their versatile, robust, and tunable electronic properties in terms of surface termination groups. In recent years, various 2D MXenes with oxygen functionalization have been explored towards robust band inversion, a non-trivial Z_2 invariant, and a large band gap [2]. In the present work, we have explored various double transition metal based carbide/nitride MXenes in terms of magnetic and topological properties. Particularly, W-based MXenes with strong SOC and magnetic elements providing exchange splitting result in a C-type antiferromagnetic ground state with a sizable gap. While the ferromagnetic state breaks TRS, surging resultant Berry curvature due to the fact that Kramer partners have opposite spins around the chemical potential. Further, Coulomb correlation plays a vital role in such a strongly correlated system, altering the gap between surface states due to the modulation of exchange splitting. The modulation of Coulomb correlation also captures the topological phase transition with surface gap closing and reopening with the appearance of chiral edge modes.

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P44

Altermagnetic spin liquid

João Augusto Sobral[1], Subrata Mandal[1], and Mathias S. Scheurer[1]

[1] *Institute for Theoretical Physics III, University of Stuttgart, 70550 Stuttgart, Germany*

In this work, we study quantum-fluctuation-driven fractionalized phases emerging near collinear altermagnetic order. Beyond the conventional magnetic orders, we find a non-coplanar "orbital altermagnet" with altermagnetic symmetries in spin-rotation-invariant observables. We also identify the neighboring fractionalized phases when quantum fluctuations destroy long-range spin order, employing the Schwinger-boson description. Although spin rotations are restored, discrete symmetries remain broken in some of these phases. In particular, the orbital altermagnet leads to an "altermagnetic spin liquid" phase.

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P45

Symmetries of Weyl Superconductors with Different Pairings

Mehran Zahiri Abyaneh[1], Mehrdad Farhoudi[1], and Mahdi Mashkoori[2,3]

[1] *Department of Physics, Shahid Beheshti University, Evin, Tehran 19839, Iran*
[2]*Department of Physics, K.N. Toosi University of Technology, P.O. Box 15875-4416, Tehran, Iran*
[2]*School of Physics, Institute for Research in Fundamental Sciences (IPM), P.O. Box 19395-5531, Tehran, Ira*

We examine the Bogoliubov-de Gennes Hamiltonian and its symmetries for a time-reversal symmetry broken three dimensional Weyl superconductor. In the limit of vanishing pairing potential, we specify that this Hamiltonian is invariant under two sets of continues symmetries, i.e. the $U(1)$ gauge symmetry and the $U(1)_A$ axial symmetry. Although a pairing of the Bardeen-Cooper-Schrieffer type spontaneously breaks both of these symmetries, we show that a Fulde-Ferrell-Larkin-Ovchinnikov type pairing spontaneously breaks only the $U(1)$ gauge symmetry (that is then restored via the well-known scalar phase mode of superconductivity). Consequently, in the former case, two Nambu-Goldstone modes are required in the system to restore the broken symmetries. We indicate that one of these two modes is an emergent pseudo-scalar phase mode. We also demonstrate that such a phase mode leads to a pseudo-Meissner effect.

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P46

Magnetic Properties of B-site Mixed Quantum Spin Liquid in the Triangular Ferromagnetic $Sr_3CuSb_2O_9$ System

R. Masrour*

[1]*Laboratory of Solid Physics, Faculty of Sciences Dhar Mahraz, Sidi Mohamed Ben Abdellah University, BP 1796, Fez, Morocco*

* rachidmasrour@hotmail.com

Abstract

Recent experimental and theoretical studies have reported that the stratified triangular system $Sr_3CuSb_2O_9$ exhibits a gapless quantum spin liquid phase, which has been extensively studied. The exchange interactions between the magnetic atoms both within the same plane and between planes are calculated using density functional theory. These results are then used as inputs for a Monte Carlo simulation with the Metropolis algorithm, applying the Ising model to investigate the magnetic and thermodynamic properties of spin-1/2 systems. Thermal magnetization, internal energy, specific heat, and magnetic hysteresis cycles are determined. The study identifies the transition temperature and superparamagnetic behavior. Additionally, superparamagnetic, ferromagnetic, and paramagnetic phases are observed. These novel magnetic properties could have potential applications in nanoelectronics, magnetic sensors, and flexible magnets.

P47

Current-induced dissociation: Topological insulators as robust reaction platforms

Erika L. Mehring [1] **, Amparo Figueroa** [1] **, Matías Berdakin**[2] **and Hernán L. Calvo**[1]

[1]*Instituto de Física Enrique Gaviola (CONICET) and FaMAF, Universidad Nacional de Córdoba, Argentina*

[2] *Facultad de Ciencias Químicas, Universidad Nacional de Córdoba, Argentina*

Catalysis at the nanoscale often depends on the ability to manipulate chemical bonds through interactions with a substrate. In this context, the use of topological materials as catalytic platforms has generated growing interest, giving rise to the emerging field of topocatalysis. These materials exhibit robust, symmetry-protected edge states that can persist in the presence of disorder, offering a novel route to stabilize and enhance catalytic processes under non-ideal conditions [1, 2, 3, 4]. A particularly intriguing possibility is the use of these edge states to drive non-equilibrium dissociation of molecules via current-induced mechanisms [5]. To this end, we study current-induced molecular dissociation at the edge of two-dimensional materials by analyzing the occupation of antibonding states in a diatomic molecule coupled to the ribbon boundary. Using the non-equilibrium Green's function formalism, we compare a pristine graphene substrate with the Kane-Mele model, the latter supporting topologically protected edge states. The bonding and antibonding energies of the molecule are embedded within the topological gap of the Kane-Mele model, while in graphene these coexist within a metallic energy region. We find that applying a bias voltage leads to a significant occupation of the molecular antibonding state, thereby destabilizing the molecular bond. Notably, while in clean samples both substrates promote antibonding occupation under clean conditions, when introducing vacancy disorder into the substrate we observe that the Kane-Mele model maintains a high antibonding occupancy, whereas in graphene this occupation sharply decreases with increasing vacancy concentration. This demonstrates a form of topological protection in the non-equilibrium dissociation mechanism, highlighting a promising route toward robust catalytic activity in topological materials.

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P48

Magnetic and Transport Properties of Fe_3O_4/RGO Nanostructures: Insights into Spin-Glass Behavior and Spintronic Applications

Mariam Omran[1], Seungyong Eom[1], Dilanath Adhikari[2], Do-hyung Kim[1], Heon-Jung Kim[2] Younjung Jo[1]

[1]Department of Physics, Kyungpook National University, Daegu 41566, Korea

[2]Department of Physics, Daegu University, Daegu 41566, Korea

Abstract:

Fe_3O_4/reduced graphene oxide (RGO) nanocomposites present a promising platform for exploring emergent quantum magnetic phenomena and advancing spintronic applications. In this study, 25 nm Fe_3O_4 nanoparticles were synthesized and integrated into an RGO matrix using the solvothermal method. Structural and compositional analyses, including X-ray diffraction (XRD), scanning electron microscopy (SEM), X-ray photoelectron spectroscopy (XPS), and Raman spectroscopy, confirmed the high quality, uniformity, and homogeneity of the hybrid nanostructures.

Magnetization (M-H) and magnetoresistance (MR) measurements performed across 2 K to 300 K temperatures and magnetic fields up to 9 T revealed distinct low-temperature quantum behaviors. The nanocomposites exhibited a pronounced negative-to-positive MR transition, coupled with enhanced spin-glass-like behavior and exchange bias effects, driven by interfacial coupling between Fe_3O_4 nanoparticles and the RGO matrix. Notably, slight compression during sample measurements amplified these effects, highlighting the sensitivity of magnetic and transport properties to external control and nanoscale interactions. This interplay of localized magnetic moments in Fe_3O_4 and delocalized π-electrons in RGO enables the hybrid system to balance ferromagnetic order with spin disorder, resulting in tunable quantum phases.

These findings establish Fe_3O_4/RGO nanocomposites as a versatile platform for understanding and controlling complex quantum orderings in 2D materials and demonstrate their potential in developing next-generation spintronic devices.

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P49

Phonon cyclotron resonance detected in Bi_2Se_3 thin films by Faraday rotation measurement

R. Nagarajan[1], **U. Nagel**[1], **and T. Rõõm**[1]

[1]*National Institute of Chemical Physics and Biophysics, Tallinn, Estonia*

Bi_2Se_3 is a 3D topological insulator with insulating bulk, and conducting surface states with Dirac-fermionic dispersion. Recent studies have reported quantized Faraday rotation in the topological surface states [1, 2, 3] of Bi_2Se_3. However, these studies were limited to magnetic fields less than 10 T. The motivation for our work was to investigate quantized Faraday rotation at higher magnetic fields, which would probe the lower Landau levels.

We present results from Faraday rotation measurement on a 8QL thick Bi_2Se_3 thin film in sub-THz frequency range, at a temperature of 3.5 K, in external magnetic field B = 1 T to 15 T, perpendicular to sample plane. The Fermi level in this Bi_2Se_3 sample is in the bulk conduction band. The observed Faraday rotation spectra show an inflection at 60 cm^{-1}, which can be attributed to phonons [1]. The spectra were analyzed using a two-oscillator Drude-Lorentz model which captures the inter-Landau level electronic transitions in the presence of phonons [1] (Fig. 1).

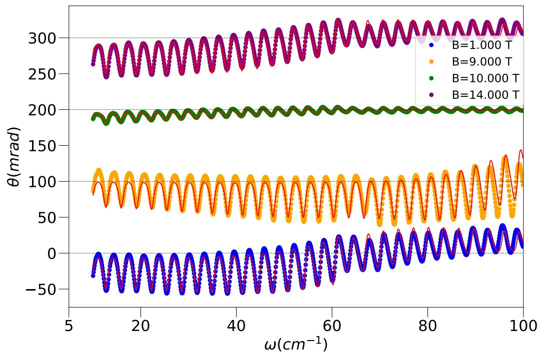

Figure 1: Faraday rotation measured in Bi_2Se_3 thin films at B = 1 T (blue), 9 T (orange), 10 T (green), and 14 T (purple). Red solid line is a fit to rotation derived from Drude-Lorentz model. Curves are vertically offset for clarity, as marked by the black dotted line. Periodic oscillations observed in the rotation arise from Fabry-Perot reflections of light in the sample substrate; this effect has been incorporated into the fit model.

From this analysis, both cyclotron and phonon resonance frequencies were extracted as a function of the applied magnetic field (Fig. 2).

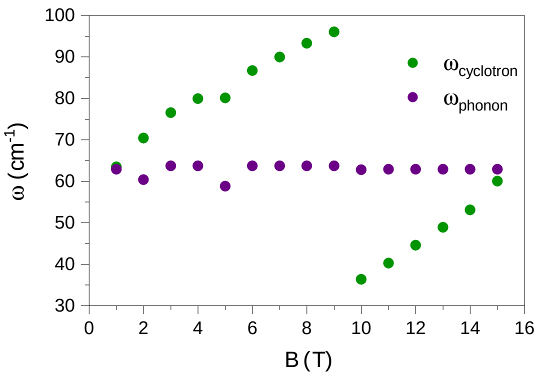

Figure 2: Cyclotron frequency (green circles) and phonon frequency (purple circles) obtained from the fit.

At low magnetic fields, we observe a cyclotron frequency which is proportional to magnetic field B but offset by phonon frequency. This can be explained by phonon-mediated inter-Landau level transitions [4]. This feature is no longer present above 10 T, where only regular inter-Landau level transitions are detected. The results indicate a magnetic-field-dependent interaction between phonons and charge carriers in Bi_2Se_3, which modifies the cyclotron resonance at low fields. This work was done in collaboration with Seongshik Oh, Rutgers University. We acknowledge discussions with Girsh Blumberg, Rutgers university. The work was supported by the Estonian science agency grant PRG736 and European research council (ERC) under the EU Horizon 2020 program Grant Agreement No. 885413.

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P50

Ground-State Selection and Braided Ising Spin-Tubes in a new Family of Breathing Kagome Magnets

J. Nagl[1], **D. Flavián**[1], **and A. Zheludev**[1]

[1]*Laboratory for Solid State Physics, ETH Zürich, 8093 Zürich, Switzerland*

The recently discovered family of rare-earth based quantum antiferromagnets R_3BWO_9 have been proposed as proximate spin-liquid candidates, realizing the highly frustrated breathing kagome lattice. We present a thorough experimental investigation on *single crystals* of the R = Pr, Nd members [1, 2, 3], including inelastic neutron scattering, neutron diffraction, thermodynamic and magnetometric measurements. Pr_3BWO_9 possesses a disordered ground state with an unusual excitation spectrum, involving a coexistence of sharp spin waves and broad continuum excitations [2]. Nd_3BWO_9 on the other hand orders magnetically at the lowest temperatures, revealing a highly anisotropic $H - T$ phase diagram including various quantum- and multicritical points [1]. Three different fractional magnetization plateaux are realized in applied fields, with distinct propagation vector and ordering pattern depending on the field orientation [3].

We combine these observations with theoretical modeling, showing that it is the *inter*-plane couplings that determine the exotic magnetism of these materials. We derive a simple one-dimensional Ising model composed of twisted triangular spin-tubes, i.e., triple braids of Ising spin chains with nearly-orthogonal anisotropy frames and competing ferro-antiferromagnetic interactions [3]. This model can account for the ground state, excitations and the numerous field-induced fractional magnetization plateau phases in Nd_3BWO_9, as well as the incommensurate magnetic correlations emerging at elevated temperatures [3]. As for Pr_3BWO_9, its non-Kramers nature allows for a small splitting of the lowest quasi-doublet states, resulting in a quantum disordered singlet ground state. It poses an ideal realization of a frustrated transverse-field Ising model, where both spectrum and thermodynamics can be modeled to astounding success [2].

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P51

In search of triplet superconductivity: dual-gated monolayer MoS2

Jericho V. Narvasa [1] , **Banan El-Kerdi** [2] , **Freek Massee**[1], **and Charis Quay** [1]

[1] *Laboratoire de Physique des Solides (LPS), Université Paris-Saclay Orsay, France 91400*
[2] *Laboratoire d'Optique Appliquée (LOA), Institut Polytechnique de Paris Palaiseau Cedex, France 91762*

The ground states of ^{3}He-superfluid and BCS superconductivity are both made up of pairs of spinful entities. The nuclei pair in the former has a spin triplet structure while the Cooper pairs in a conventional superconductor are spin singlet. This raises the question for the possible existence of spin triplet superconducting states [1].

A recent theoretical work on a particular pairing of triplet superconductor called equal-spit triplet pairing (ESTP) is predicted to emerge in thin layers of TMDs under the influence of an in-plane magnetic field that competes with the Ising spin-orbit coupling [2]. These ESTPs can be manifested as *mirage gaps*, which are finite replicas of the main superconducting gaps found on its either sides.

Our group has previously made an effort to measure the density of states of superconducting bilayer $NbSe_2$ in a contact tunneling spectroscopy with WSe_2 barrier in a wide range of in-plane magnetic field of up to 30 T [3]. Despite the absence of mirage gaps, evidence of triplet pairing was observed by fitting the superconducting gap function that takes into account triplet pairs. The lack of mirage gap in the tunneling spectra can be explained by the effects of trigonal warping in the natural fermi level of $NbSe_2$ which can easily obscure such small features.

In order to address this, we fabricated monolayer-MoS_2 transistors gated with HfO_2 on top and SiO_2 at the bottom. The idea of this device is to be able to control the carrier concentration of MoS_2 and move the fermi level closer to the band edge to avoid trigonal warping, and simultaneously control the electric field through the TMD. Previous studies report superconducting phase transition of monolayer MoS_2 at $\eta_c = 6 \times 10^{13}$ cm^{-2} with ionic liquid gate [4]. Our preliminary results with solid gates show that we can achieve a carrier concentration of up to 1×10^{14} cm^{-2} large enough to facilitate superconducting phase transition at 4K with both of the gates being active. This promising finding leads us to design devices where we can simultaneously gate the monolayer TMD and at the same time perform tunneling measurements.

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P52

Canted magnetism and $\mathbb{Z}_2$ fractionalization in metallic states of the Lieb lattice Hubbard model near quarter filling

Alexander Nikolaenko,* Pietro M. Bonetti,* Anant Kale,

Martin Lebrat, Markus Greiner, and Subir Sachdev

Department of Physics, Harvard University, Cambridge MA 02138, USA

Abstract

A recent experiment has examined ultracold, fermionic, spin-1/2 ^{6}Li atoms in the Lieb lattice at different Hubbard repulsion U and filling fractions ν (Lebrat *et al.* arXiv:2404.17555). At $\nu = 1/2$ and small U, they observe an enhanced compressibility on the $p_{x,y}$ sites, pointing to a flat band near the Fermi energy. At $\nu = 1/2$ and large U they observe an insulating ferrimagnet. Both small and large U observations at $\nu = 1/2$ are consistent with theoretical expectations. Surprisingly, near $\nu = 1/4$ and large U, they again observe a large $p_{x,y}$ compressibility, pointing to a flat $p_{x,y}$ band of fermions across the Fermi energy. Our Hartree-Fock computations near $\nu = 1/4$ find states with canted magnetism (and related spiral states) at large U, which possess nearly flat $p_{x,y}$ bands near the Fermi level. We employ parton theories to describe quantum fluctuations of the magnetic order found in Hartree-Fock. We find a metallic state with $\mathbb{Z}_2$ fractionalization possessing gapless, fermionic, spinless 'chargons' carrying $\mathbb{Z}_2$ gauge charges which have a nearly flat $p_{x,y}$ band near their Fermi level: this fractionalized metal is also consistent with observations. Our DMRG study does not indicate the presence of magnetic order, and so supports a fractionalized ground state. Given the conventional ferrimagnetic insulator at $\nu = 1/2$, the $\mathbb{Z}_2$ fractionalized metal at $\nu = 1/4$ represents a remarkable realization of doping-induced fractionalization.

* These authors contributed equally to this work.

P53

RKKY quadratic and biquadratic spin-spin interactions in twisted bilayer graphene

Smr 4094 - Joint ICTP-WE Heraeus School and Workshop on Advances in Quantum Matter: Pushing the Boundaries

D. O. Oriekhov [1], **T. T. Osterholt**[2], **R. A. Duine**[2,3], **and V. P. Gusynin**[4]

[1]*Kavli Institute of Nanoscience, Delft University of Technology, 2628 CJ Delft, the Netherlands*

[2]*Institute for Theoretical Physics, Utrecht University,*

Princetonplein 5, 3584CC Utrecht, The Netherlands

[3]*Department of Applied Physics, Eindhoven University of Technology,*

P.O. Box 513, 5600 MB Eindhoven, The Netherlands

[4]*Bogolyubov Institute for Theoretical Physics, Kyiv, 03143, Ukraine*

We study the competition between the RKKY quadratic and biquadratic[1] spin-spin interactions of two magnetic impurities in twisted bilayer graphene away from the magic angle. We apply the Bistritzer-MacDonald model [2] of two graphene layers twisted with respect to each other by a small angle. By reducing the model to the Dirac-type one with modified Fermi velocity, we derive expressions for the RKKY quadratic and biquadratic spin interactions using perturbation theory for the free energy. The biquadratic interaction is suppressed by a larger power of the interaction constant and decreases faster with the distance between impurities comparing to the quadratic one. Nevertheless, due to the different period of oscillations with impurity separation distance, chemical potential, twist angle and temperature, it is possible to fine-tune the system to the regime of dominating biquadratic interaction. Such a regime might be characterized by non-conventional spin order parameters such as quadrupole order [3].

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P54

Non-trivial entanglement passively mediated by a Kondo impurity

A. A. Orlandini[1], **G. G. Blesio**[1,2], **C. J. Gazza**[1] **and L. O. Manuel**[1]

[1] *Instituto de Física Rosario (CONICET) and Facultad de Ciencias Exactas, Ingeniería y Agrimensura (UNR)*
[2] *Jožef Stefan Institute, Jamova 39, SI-1000 Ljubljana, Slovenia*

A quantum phase transition between two topological distinct local Fermi liquids takes places in the two-channel spin-1 Kondo impurity model as a function of the single-ion anisotropy. In this work, we numerically study the entanglement properties of the systems across this quantum phase transition. In the usual Kondo phase, for lower anisotropies, the entanglement cloud surrounding the magnetic impurity mimics the Kondo screening cloud. On the other side of the transition, in the *non-Landau* Fermi liquid phase, there is a non-trivial entanglement structure: while the impurity is disentangled from the rest of the system due to the destruction of the Kondo effect by the anisotropy, the two conduction channels, that are coupled only through the impurity, become highly entangled between them. Our results shows that a magnetic impurity can passively mediate the entanglement between spatially separated conduction bands.

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P55

Exotic superconducting states in altermagnets

Kirill Parshukov and Andreas P. Schnyder

Max Planck Institute for Solid State Research, Heisenbergstrasse 1, D-70569 Stuttgart, Germany

The interplay between magnetism and superconductivity is one of the central topics of condensed matter physics, which has recently been put into new light by the discovery of altermagnets. Here, we study this interplay from a fundamental symmetry perspective using irreducible co-representations of the altermagnetic spin-point groups. We construct and tabulate all symmetry-allowed pairing functions for altermagnets, which uncovers numerous exotic pairing states. We focus on three of them, namely: (i) a non-unitary superconductor with different spatial anisotropies for the spin-up and spin-down condensates, (ii) a half-and-half metal-superconductor where only electrons with one of the two spin components form Cooper pairs, and (iii) a spin chiral superconductor with spin-polarized edge states. Interestingly, the first of these three superconductors exhibits an unusual fractional ac Josephson current for only one of the two spin polarizations. We present phenomenological Ginzburg-Landau theories for these unconventional superconductors and show that they correspond to stable solutions of the free energies. We examine their topological properties, study the effects of small spin-orbit coupling, consider possible material examples, and investigate their topological responses.

P56

Quasiparticle band picture bridging topology and strong correlations across energy scales

Ivan Pasqua[1], Antonio M. Tagliente[1], Gabriele Bellomia[1], Bartomeu Monserrat[2,3], Michele Fabrizio[1], and Carlo Mejuto-Zaera[4]

[1] *International School for Advanced Studies (SISSA), Via Bonomea 265, I-34136 Trieste, Italy*

[2] *TCM Group, Cavendish Laboratory, University of Cambridge, J.J. Thomson Avenue, Cambridge CB3 0HE, United Kingdom*

[3] *Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, Cambridge CB3 0FS, United Kingdom*

[4] *Univ Toulouse, CNRS, Laboratoire de Physique Théorique, Toulouse, France*

Understanding the interplay between electronic correlations and band topology remains a central challenge in condensed matter physics, primarily hindered by a language mismatch problem. While band topology is naturally formulated within a single-particle band theory, strong correlations typically elude such an effective one-body description. In this work, we bridge this gap leveraging the ghost Gutzwiller (gGut) variational embedding framework, which introduces auxiliary quasiparticle degrees of freedom to recover an effective band structure description of strongly correlated systems. This approach enables an interpretable and computationally efficient treatment of correlated topological phases, resulting in energy- and momentum-resolved topological features that are directly comparable with experimental spectra. We exemplify the advantages of this framework through a detailed study of the interacting Bernevig-Hughes-Zhang model. Not only does the gGut description reproduce established results, but it also reveals previously inaccessible aspects: most notably, the emergence of topologically nontrivial Hubbard bands hosting their own edge states, as well as possible ways to manipulate these through a finite magnetization. These results position the gGut framework as a promising tool for the predictive modeling of correlated topological materials.

P57

Quench dynamics of hard-core bosons in the extended Bose-Hubbard model

Boni Paul [1], **Manpreet Singh** [1], **and Bhanu Pratap Das** [1,2]

[1] *Centre for Quantum Engineering Research and Education, TCG centers for Research and Education in Science and Technology, Sector V, Salt Lake, Kolkata 700091, India*
[2] *Department of Physics, School of Science, Tokyo Institute of Technology, Ookayama, Meguro-ku, Tokyo 152-8550, Japan*

In this work, we examine the quench dynamics of hard-core bosons in a one-dimensional optical lattice at half-filling within the extended Bose-Hubbard (EBH) model. Using the Matrix Product State (MPS) method, we analyze the equilibrium phases first, identifying the superfluid (SF) and density-wave (DW) phases and estimating the quantum critical point separating them. These analyses provide a comprehensive foundation for exploring the quench dynamics of the EBH model.

Focusing on the quench dynamics, we investigate the system's response to a linear quench of the nearest-neighbour interaction (NNI), driving it from the SF to the DW phase through the quantum critical point. Observables such as on-site density, momentum distribution, and structure factor are studied across slow, intermediate, and fast quenches for different system sizes.
Inspired by the Kibble-Zurek mechanism of defect formation observed in other contexts, we examine its applicability to our system. To this end, we calculate the residual energy of the quenched state, which serves as a measure of defects generated at various quench rates and system sizes. We then compare our results to the scaling law that links defect density to the quench rate, demonstrating the characteristics of the Kibble-Zurek mechanism. Our findings provide insights into the universal dynamics of phase transitions in strongly correlated quantum systems.

P58

Fractional chiral second-order topological insulator from a three-dimensional array of coupled wires

Viktoriia Pinchenkova[1], **Katharina Laubscher**[2], **and Jelena Klinovaja**[1]

[1]*Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland*

[2]*Condensed Matter Theory Center and Joint Quantum Institute, Department of Physics, University of Maryland, College Park, MD 20742, USA*

We construct a model of a three-dimensional chiral second-order topological insulator (SOTI) from an array of weakly coupled nanowires. We show that, in a suitable parameter regime, the interplay between rotating magnetic fields and spatially modulated interwire tunnelings leads to the opening of gaps in the bulk and surface spectrum of the system, while one or more chiral hinge states propagating along a closed path of one-dimensional hinges are left gapless. The exact path of these hinge states is determined by the hierarchy of interwire couplings and the boundary termination of the sample. Depending on the ratio between the period of the rotating magnetic field and the Fermi wavelength, our model can realize both integer and fractional chiral SOTIs. The fractional regime emerges in the presence of strong electron-electron interactions and features hinge states carrying only a fraction e/p of the electronic charge e for a positive odd integer p.

For more details, see our preprint [1].

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P59

Concealed Mott Criticality:
Unifying the Kondo Breakdown and Doped Charge-Transfer Insulators

Louk Rademaker [1,2]

[1]Department of Quantum Matter Physics, University of Geneva, Switzerland
[2]Institute-Lorentz for Theoretical Physics, Leiden University, The Netherlands

I show that the quantum critical points observed in heavy fermions (the 'Kondo breakdown') and in doped cuprates can be under- stood in terms of concealed Mott criticality.[1] In this picture, one species of electrons undergoes a Mott localization transition, in the presence of metallic charge carries. As is shown in a simple toy model, this results in a Fermi surface jump at the transition, as well as mass enhancement on both the 'large' and 'small' Fermi surface side of the transition, consistent with the experimental observations.

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P60

Fascinating mesoscale magnetic textures in the topological Kagome system $TbMn_6Sn_6$

Ralph Rajamathi[1], Manuel Zahn[1,2], Kai Litzius[1], István Kézsmárki[1], Sándor Bordács[3]

[1]*Center for Electronic Correlations and Magnetism, University of Augsburg*
[2]*Department of Materials Science and Engineering, Norwegian University of Science and Technology*
[3]*Department of Physics, Budapest University of Technology and Economics*

In recent years, the Kagome ferrimagnet $TbMn_6Sn_6$ has garnered significant interest due to its unconventional band topology, which realizes exotic quantum states like a Chern insulating phase [1]. It exhibits a spin-reorientation transition (SRT) from easy-axis to easy-plane above 310K, where skyrmion bubbles have been observed in lamellae [2]. Less, however, is known about the bulk magnetic textures in this system. Here, we used magnetic force microscopy (MFM) to image the magnetic structure of $TbMn_6Sn_6$, and magnetometry to study the role of second order magnetic anisotropy. Two types of textures were observed, namely long-ranged stripes that invert contrast on reversing the tip's magnetization, and smaller star-shaped structures that do not invert, possibly indicating two different magnetization mechanisms. The effect of an external magnetic field was also studied, showing that the textures were indeed affected by the same. Analyzing the in-plane magnetometry data, a metastable magnetization state was observed for curves below the SRT temperature, indicating the possibility of an intermediate canted state. This was confirmed via temperature-dependent MFM, where three distinct contrasts were observed.

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P61

Zeeman spin-orbit coupling in antiferromagnetic conductors

Revaz Ramazashvili [1]

[1] *Laboratoire de Physique Théorique, Université de Toulouse, CNRS, UPS, Toulouse, France*

Electron spectra of antiferromagnetic conductors in external magnetic field host remarkable symmetry-protected degeneracies, that render the Zeeman splitting substantially momentum-dependent, and thus turn it into a spin-orbit coupling. I will discuss experimental evidences [1] of this phenomenon, its symmetry underpinnings [2] – and will compare it with altermagnetic splitting, that has been attracting much attention lately.

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P62

Tunability of moiré phonons in twisted homobilayers.

Alejandro Ramos-Alonso[1]

[1] *Department of Physics, Columbia University, New York, NY 10027, USA*

Moiré structures of 2D materials generically form incommensurate superlattices. Among the collective vibrations of the moiré pattern (*moiré phonons*), there are two acoustic branches (*phasons*) resulting from the free-energy invariance with respect to global, relative translations of the layers. In homobilayers with polar domains, out-of-plane electric fields dramatically alter the moiré phonon dispersion [1]. In transition metal dichalcogenides in particular, twisting around a noncentrosymmetric configuration implies the formation of local polar domains tied to the local stacking order. In the presence of an external out-of-plane electric field, the symmetries of the energy landscape change, the longitudinal phason dispersion softens, and the moiré phonons acquire nonzero angular momentum. Several optical modes and one of the acoustic branches become flat at experimentally realizable fields, enhancing the vibrational density of states. As a consequence, electron-phonon coupling (EPC) effects may become larger, which would affect experimental quantities such as the electric resistivity.

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P63

Superconducting diode effect due to higher order magnetic toroidal moments

Anant Rastogi[1], **Turan Birol**[1], **and Rafael M. Fernandes**[2]

[1] *University of Minnesota*
[2] *University of Illinois, Urbana Champaign*

The superconducting diode effect (SDE), by which the critical current along a certain direction is different from the critical current along the reciprocal direction, has been widely discussed in systems that experience an effective electric field and an external magnetic field. This combination of fields can give rise to a magnetic toroidal dipole moment, which in turn ensures the existence of a Lifshitz invariant in the superconducting Ginzburg-Landau free energy. Here, we consider instead the case of magnetically ordered systems that host magnetic toroidal octupole moments. By analyzing the Ginzburg-Landau free energies for single-component as well as multicomponent superconducting order parameters, we find a cubic-in-momentum term that can stabilize both the SDE and a pair density wave. We also discuss the magnetic symmetries responsible for this behavior.

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$\mathbb{Z}_N$ Lattice Gauge Theories with Matter Fields

Kaustubh Roy[1] and **Elio J. König**[2]

[1]*Department of Physics and Astronomy, Rutgers University, New Jersey, USA*

[2]*Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany*

Motivated by the exotic phenomenology of certain quantum materials and recent advances in programmable quantum emulators, we here study fermions and bosons in $\mathbb{Z}_N$ lattice gauge theories. We introduce a family of exactly soluble models, and characterize their orthogonal (semi)metallic ground states, the excitation spectrum, and the correlation functions. We further study integrability-breaking perturbations using an appropriately derived set of Feynman diagrammatic rules and borrowing physics associated to Anderson's orthogonality catastrophe. In the context of the ground states, we revisit Luttinger's theorem following Oshikawa's flux insertion argument and furthermore demonstrate the existence of a Luttinger surface of zeros in the fermionic Green's function. Upon inclusion of perturbations, we address the transition from the orthogonal metal to the normal state by condensation of certain excitations in the gauge sectors, so-called "e particles." We furthermore discuss the effect of dynamics in the dual "m-particle" excitations, which ultimately leads to the formation of charge-neutral hadronic N-particle bound states. We present analytical arguments for the most important phases and estimates for phase boundaries of the model. Specifically, and in sharp distinction to quasi-one-dimensional $\mathbb{Z}_N$ lattice gauge theories, renormalization group arguments imply that the phase diagram does not include an emergent deconfining $U(1)$ phase in the limit of large number of fermion flavors. Therefore, in regards to lattice QED problems, $\mathbb{Z}_N$ quantum emulators with $N < \infty$ can at best be used for approximate solutions at intermediate length scales.

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Emergence of Nematic Ordering from Two-Magnon Bound States on Frustrated Triangular Lattices

László Rudner[1,2], **Karlo Penc**[2]

[1]*Budapest University of Technology and Economics*
[2]*HUN-REN Wigner Research Centre for Physics*

Excitations, known as magnons in magnetic systems, determine low-temperature properties such as specific heat and magnetic susceptibility and provide insights into the nature of the ground state. Magnons can interact strongly, potentially forming two-magnon bound states whose behavior remains less well understood compared to single-magnon excitations. The nature of this interaction determines the resulting ordered phase: repulsive interactions lead to antiferromagnetic phases upon magnon condensation, whereas attractive interactions can induce condensation of two-magnon bound states, resulting in nematic phases without breaking time-reversal symmetry.
This study investigates two-magnon excitations in the Heisenberg model on a triangular lattice incorporating ferromagnetic and antiferromagnetic interactions between first-, second-, and third-nearest neighbors. Using the Luttinger-Tisza method, I constructed the model's phase diagram and calculated magnon dispersion relations starting from the ferromagnetic regime, including the phase boundaries to antiferromagnetic phases. Subsequently, I derived and solved the Schrödinger equation describing two-magnon interactions via a self-consistent approach, decomposing the interaction into partial-wave components. At high-symmetry Γ and K points in the Brillouin zone, the self-consistent equations simplify according to irreducible representations of the D_6 point group. I identified parameter regimes where nematic phases can arise by analyzing conditions under which the bound-state energy gap closes at the ferromagnetic phase boundary. Finally, I validated the analytical findings using exact diagonalization calculations and provided additional insights into effective interactions between the two-magnon bound states by studying the behavior of three- and four-magnons.

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Probing Topology of The Kitaev Chain Using a Mobile Impurity

A. Sadovnikov[1,2], M. Bahovadinov[1], A. Markov[1] and A. Rubtsov[1,3]
[1] *Russian Quantum Center, Skolkovo IC, Moscow 121205, Russia*
[2] *Moscow Institute of Physics and Technology, 117303 Moscow, Russia and*
[3] *Department of Physics, Lomonosov Moscow State University, 119991 Moscow, Russia*

We investigate the behavior of a Kitaev wire locally interacting with a single mobile impurity. Using the Exact Diagonalization method, we have found that one impurity doesn't break a topology of the Kitaev chain, besides the behavior of impurity differ in the topological and trivial phases. In the topological phase there is a smooth crossover between a polaron state and a molecule state, while in the trivial one there is a sharp jump in the correlation functions, indicating a quantum phase transition. In the open chain the impurity can localize at the edges of the chain in both topological and trivial phases. In this case the Majorana zero bias can't be used as an indicator of the unpaired Majorana modes, but we found that the energy gap between the ground state and first exited state is connected with the bulk majorana-majorana correlation function $\langle \gamma_i^2 \gamma_{i+1}^1 \rangle$.

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Emergent Topology in Moiré $MoTe_2/WSe_2$ Heterostructures

Palash Saha [1], **Louk Rademaker** [2], **and Michał Zegrodnik** [2]

[1] *AGH University of Krakow, Academic Centre for Materials and Nanotechnology AGH, A. Mickiewicza Av. 30, 30-059 Krakow, Poland*

[2] *Department of Quantum Matter Physics, University of Geneva, CH-1211 Geneva, Switzerland*

psaha@agh.edu.pl
michal.zegrodnik@agh.edu.pl

We investigate the emergence of topological phases in bilayer $MoTe_2/WSe_2$, emphasizing the crucial influence of spin-orbit coupling [1] and strong electron correlations. Our theoretical analysis uncovers the presence of quantum anomalous Hall (QAH) [2] and quantum spin Hall (QSH) states within a tuneable moiré superlattice, shedding new light on the intricate relationship between spin order and topology.

In the regime of one hole per moiré unit cell, we identify a unique spin arrangement where a combination of in-plane 120° antiferromagnetic order and out-of-plane order gives rise to a canted spin phase. Under specific bias conditions, this canted configuration acquires a finite Chern number, aligning with experimental findings [3]. These insights underscore the potential of bilayer $MoTe_2/WSe_2$ for spintronic applications, as it offers a controllable platform for engineering nontrivial topological states.

For the case of two holes per moiré cell—where experimental signatures of the QSH phase have been observed [4]—we demonstrate that long-range Coulomb interactions alone can effectively mediate hopping, coupling two essential orbitals and generating topologically nontrivial bands. This interaction-driven mechanism mirrors key experimental discoveries and opens new avenues for tuning emergent phenomena in two-dimensional semiconductor heterostructures.

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P68

Frustrated multipolar degrees of freedom: The quadrupolar Kitaev model (For presentation in ICTP School & workshop | smr 4094)

Partha Sarker[1], Urban F. P. Seifert[1]

[1]*(Presenting author underlined) Institute for Theoretical Physics, University of Cologne, Zülpicher Straße 77, D-50937 Köln*

Frustrated multipolar exchange interactions between spin-S local moments ($S > \frac{1}{2}$) have been suggested to possibly give rise to quantum spin liquid-like ground states featuring an emergent gauge structure and fractionalized excitations. However, only little is known about characteristic features and experimental signatures of such "multipolar spin liquids". To this end, in this work we turn to the "Quadrupolar Kitaev model" of $S = 1$ moments on a honeycomb lattice as a drosophila, for which recent numerical studies [1] have indicated a signature of deconfined ground state with $\mathbb{Z}_2$ topological order. As the quadrupolar spin-1 Kitaev model, similar to the spin-S generalization of the Kitaev honeycomb model, is not exactly solvable, we use a combination of mean-field theory and exact symmetry analysis to investigate competing ground states, including multipolar liquids, and their (fractionalized) excitations. Our work suggests that for isotropic couplings $(J_x = J_y = J_z)$, there exists a extensive set of ground state configurations at the mean field level. Using a generalized parton construction [2], we identify an exact gauge structure using 1-form symmetries of the model.

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P69

Fractionalized Altermagnets: from neighboring and altermagnetic spin-liquids to fractionalized spin-orbit coupling

<u>João Augusto Sobral</u>[1], Subrata Mandal[1], and Mathias S. Scheurer[1]

[1]*(Presenting author underlined) Institute for Theoretical Physics III, University of Stuttgart, 70550 Stuttgart, Germany*

We study quantum-fluctuation-driven fractionalized phases in the vicinity of altermagnetic order. First, the long-range magnetic orders in the vicinity of collinear altermagnetism are identified; these feature a non-coplanar "orbital altermagnet" which has altermagnetic symmetries in spin-rotation invariant observables. We then describe neighboring fractionalized phases with topological order reached when quantum fluctuations destroy long-range spin order, within Schwinger-boson theory and an SU(2) gauge theory of fluctuating magnetism. Discrete symmetries remain broken in some of the fractionalized phases, with the orbital altermagnet becoming an "altermagnetic spin liquid". We compute the electronic spectral function in the doped system, revealing "fractionalized spin-orbit coupling" characterized by split Fermi surfaces, reminiscent of conventional spin-orbit coupling, but with preserved spin-rotation symmetry.

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Pauli Limiting Near A Quantum Critical Point

Veronika C. Stangier[1], **Davide Valentinis**[1,2], **and Jörg Schmalian**[1,2]

[1] *Institute for the Theory of Condensed Matter, Karlsruhe Institute of Technology*
[2] *Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology*

Applying a magnetic field to a superconductor reduces the critical temperature and eventually leads to the break down of the superconducting phase. Usually, this is caused by orbital coupling of the electrons to the magnetic fields. However, in systems where these orbital effects do not play a role, the superconducting phase is instead destroyed by Zeeman coupling. In a conventional superconductor this is referred to as Pauli limiting.

Near a quantum critical point, a conflicting effect occurs and the superconducting transition temperature is enhanced. Naturally, the question arises of what happens if these two effects compete.

In this work, we look at Zeeman coupling in a superconductor near a quantum critical point within the framework of Eliashberg theory. We consider a singlet superconductor where the electrons are coupled by a boson that is based on the γ-model[1]. In this way our analysis is applicable to several types of quantum critical points, e.g. nematic or antiferromagnetic. Solving both the linearized and non-linearized gap equations we discuss the emergence and break down of several superconducting phases induced by the magnetic field.

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P71

First Principle Calculations for Charge Density Waves and Strong Thermoelectric Behavior in Copper Selenide

Thomas W. Steele[1], **Sergey Y. Savrasov**[1]

[1] *University of California, Davis, United States of America*

The band structure of copper selenide was calculated through relativistic spin polarized DFT, confirming it is a Dirac semimetal in both the cubic and rhombohedral phases. The cubic phase exhibits heavy fermi surface nesting when doped, consistent with experimental signatures of charge density waves. The rhombohedral phase gains strong thermoelectric behavior.

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Theory for optical control of correlated states in moiré transition metal dichalcogenide heterostructures

Haoyang Tian[1] **and Urban F. P. Seifert**[1]

[1]*Institute for Theoretical Physics, University of Cologne, Zülpicher Str. 77a, 50937 Köln, Germany*

In recent years, moiré transition metal dichalcogenide (TMD) heterostructures have emerged as highly versatile platforms for investigating phases and phenomena of strongly correlated electrons on emergent lattice scales. However, experimental characterization of the precise nature of some interaction-driven long-range ordered states and their excitations has remained a challenge. Given strong light-matter couplings and valley selection rules in TMD materials, ultrafast optical methods may constitute a promising avenue for probing and controlling these states and their collective modes. In this work, we develop a theoretical framework to describe coherent light-matter interactions in moiré TMD heterostructures, and model the system's steady-state and non-equilibrium dynamics during and after photoexcitation with a laser pulse. Thus obtained characteristic signatures of the system's dynamics may allow for new experimental insights.

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We show that the Ruderman-Kittel-Kasua-Yoisida interaction in two channel Kondo impurity systems is a relevant perturbation when the number of impurities N is greater than 3. We find a new critical point with anomalous dimensions 1/(N+1) for the spin operator and the Sommerfeld coefficient of the specific heat scales as $\gamma \sim T^{(-3/(N+1)}$

Inter-channel hybridization plays the role of the most relevant operator at this fixed point having anomalous dimensions (N-1)/(2N+2). The critical point universal properties are relevant to many strong correlation problems, such as impurity placed in a Majorana metal and the multichannel Kondo lattice model of heavy fermion materials. We discuss relevance of our results for cluster DMFT studies of quantum criticality.

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Joint ICTP-WE Heraeus School and Workshop on Advances in Quantum Matter: Pushing the Boundaries

Title
"Quasi-classical mapping of exciton dynamics in Twisted Bilayer Graphene"

Authors
Llinersy Uranga Piña[1,2], Aliezer Martinez-Mesa[1]
[1] *Faculty of Physics, University of Havana, Havana, Cuba*
[2] *University of Toulouse III - Paul Sabatier, Toulouse, France*

Abstract
We investigate the exciton dynamics of twisted bilayer graphene formed by stacking two honeycomb carbon lattices at a small twist angle. We explore the controllability of quantum states (i.e., the Mott and the extended exciton phases), and the sensitivity to the twist angle using a model tight-binding Hamiltonian. The latter is augmented by a Hubbard and an interlayer hopping term, which account for the effects of electronic interactions and of interlayer voltage bias[1]. The Meyer-Miller mapping of quantum dynamics into a quasi-classical description of the exciton dynamics and time-resolved spectroscopy[2,3]. The capability of the mapping formalism to simulate time- and frequency-resolved spectra of two-dimensional materials is discussed.

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P75

Superconducting phase crystals and Majorana flat bands with inhomogeneous magnetic fields

Sushanth Varada [1], Patric Holmvall [1], Aksel Kobiałka[1], Ankita Bhattacharya[1], and Annica Black-Schaffer [1]

[1] *Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden*

Phase crystal [1, 2] is a nonuniform superconducting ground state characterized by spatially periodic phase modulations that break time-reversal and translational symmetries. It forms by Doppler shifting flat bands of zero-energy states that hinder superconductivity. What if these zero-energy states were flat bands of Majorana bound states? Will a phase crystal emerge along the edges of such a topological superconductor?

Recently, 2D Yu-Shiba-Rusinov lattices have emerged as a promising platform for engineering topological superconductivity. We aim to investigate whether a phase crystal can arise in an inhomogeneous magnet-superconductor hybrid system hosting Majorana flat bands [3].

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P76

Research Abstract

In recent years, magnetic textures have emerged as promising candidates for quantum information processing. However, achieving scalability and robust information transfer with these systems remains a major challenge. In this work, we propose a hybrid magnetic platform that couples two types of topological spin textures to enable robust and tunable quantum transmission. Specifically, we combine stationary skyrmion qubits, engineered in inversion-symmetric magnets [1], with mobile domain walls in magnetic racetracks [2], interacting purely through magnetic coupling. We demonstrate that the effective unitary evolution of this system is highly tunable via the velocity of the domain wall, allowing dynamic control of the skyrmion-domain wall interaction. This hybrid architecture offers a twofold advantage: mobile domain walls can serve as carriers of quantum information between distant skyrmion qubits, or, alternatively, stationary skyrmion qubits can be used to manipulate the quantum states of mobile domain walls.

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Enhancing superconductivity using thermal bosons

Ekaterina Vlasiuk [1] , **Eugene Demler** [2] , **and Richard Schmidt** [1]

[1] *Institute for Theoretical Physics, Heidelberg University, Philosophenweg 16, 69120 Heidelberg, Germany*

[2] *Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland*

How to obtain a larger critical temperature for a given superconductor? Are there bounds on the critical temperature [1]? We answer the question of how to increase the critical temperature and whether it is possible to go from one critical bound to another. If we have a phonon-mediated superconductor, then the Debye energy is the bound. But what if we couple this superconductor to another medium? We study what happens to the superconducting critical temperature when we add bosonic particles to a three-dimensional superconductor. In recent years modifications to boson-induced superconductors have come into view in light of the cold atomic systems and two-dimensional solid-state materials [2,3]. The story of modifications started from BEC-mediated interactions and the use of the effective Froehlich model for its description. Later, it was realized that bound state physics between bosons and fermions is important, and terms beyond the Froehlich model are essential. Now, we answer the question of what happens to the critical temperature if one adds non-condensed bosons. This is a complex problem as our system does not have a clear scale separation, so in order to tackle it, we use the Functional Renormalisation Group (FRG) approach [4]. We find that the critical temperature increases for different values of the scattering length between fermions, including the unitary limit. Therefore, the addition of bosonic particles helps to overcome the bound on the critical temperature.

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P78

Spin-Singlet Quantum Hall Phase at $\nu = 1$

T. Vouillot[1], **L. Herviou**[1], **and C. Repellin**[1]

[1] *Laboratoire de Physique et Modélisation des Milieux Condensés (CNRS Grenoble, France)*

In the context of the Integer Quantum Hall Effect (IQHE), a spinful electron gas confined to two dimensions under a perpendicular magnetic field typically yields a ferromagnetic ground state at odd integer fillings [1]. Although a rigorous proof of this quantum Hall ferromagnetism is still lacking, strong numerical evidence supports its emergence in systems with repulsive Coulomb interactions within the Lowest Landau Level (LLL), even in the limit of vanishing Zeeman energy [2]. We numerically identify a spin-singlet ground state at filling factor $\nu = 1$, achieved by tuning the electronic interaction. This phase remains stable under a realistic interaction potential derived from a modified gate-screened Rytova-Keldysh model [3]. The resulting state exhibits no real-space symmetry breaking and shares characteristics with correlated Fermi liquids. Our results could be especially relevant to moiré materials with topological flat bands, where the quantized Hall effect is observed in the absence of a magnetic field.

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P79

Effects of Kitaev interaction in f-electron systems

Bogeng Wen[1], **and Hae-Young Kee**[1]

[1]*Department of Physics, University of Toronto Canada*

The bond-dependent Kitaev interaction in the honeycomb lattice has recently garnered significant attention, as it offers a rare and exactly solvable quantum spin liquid. This interaction, which arises due to strong spin-orbit coupling (SOC), plays a crucial role in the realization of novel quantum phases. The discovery of its significance has led to extensive theoretical and experimental efforts to identify suitable material candidates that exhibit this interaction.

It was first demonstrated that SOC is an essential ingredient for the Kitaev interaction, prompting researchers to explore heavy transition-metal compounds with strong SOC effects. Among these, materials such as $\mathrm{A_2IrO_3}$[1] and α-$\mathrm{RuCl_3}$[2] have emerged as promising candidates, as they feature the necessary bond-dependent exchange interactions that give rise to the Kitaev model.

Beyond transition-metal compounds, heavy f-electron systems have also been proposed as alternative platforms for realizing the Kitaev interaction[3]. These materials are particularly intriguing due to their strong electronic correlations and the formation of a pseudospin state, which can support highly anisotropic exchange interactions. The presence of localized felectrons and their complex orbital configurations further enrich the possible quantum phases that can emerge in these systems.

In this work, we present a microscopic theoretical framework to understand the origin and realization of the Kitaev interaction across different f-electron filling configurations. By analyzing the interplay between SOC, crystal field effects, and exchange interactions, we identify scenarios where the Kitaev interaction arises in addition to other interactions. We also explore the effects of this interaction in frustrated lattices, where competing interactions can lead to unconventional magnetic ordering patterns. Our findings provide valuable insights into the design principles for realizing Kitaev physics in f-electron materials and highlight new directions for experimental exploration.

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Variational Auxiliary Field Quantum Monte Carlo Study of Hubbard Model

Indra Yudhistira[1,3], **Johannes Hofmann**[2], **and Fakher Assaad**[1,3]

[1]*Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074 Würzburg, Germany*

[2]*Max-Planck-Institut für Physik Komplexer Systeme, Nöthnitzer Strasse 38, 01187 Dresden, Germany*

[3]*Cluster of Excellence ct.qmat, Universität Würzburg, 97074 Würzburg, Germany*

When the Quantum Monte Carlo simulations are free from the notorious fermion sign problem, they can reliably simulate interacting quantum many-body system with large system size and low temperature to reveal low-energy physics. However, many interesting phenomena are elusive to be probed by Auxiliary Field QMC due to the sign problem. A particularly interesting, yet rarely explored methods of solving many-body problem is by fusing variational parameters into the auxiliary field QMC, dubbed VAFQMC, pioneered by S. Sorella [1], where he introduced variational trial wave-function and a variational form of projection operator. In particular, the variational mean-field trial wave function ansatz assume the form of $|\psi_{\mathrm{MF}}(\boldsymbol{\alpha}_0)\rangle$, while the variational projection operator has the form of $\exp[-\Theta(\hat{H}_{\mathrm{MF}}(\boldsymbol{\alpha})+\hat{V})]$, with projection parameter Θ. This new set of variational parameters $\{\boldsymbol{\alpha}_0,\boldsymbol{\alpha}\}$ are then optimized simultaneously by minimizing the ground state energy. In a preceding work, Vaezi et. al. [2] introduce the so-called adiabatic quantum Monte Carlo method, where the Hubbard interaction stength in the projection operator is gradually increased as projection parameter grows. This was shown to ameliorate the sign problem. However, in their work, the form of the time-dependent Hubbard interaction is set in ad-hoc manner rather than treated as a variational parameter.

In this preliminary work, as testing ground we perform the variational auxiliary field Quantum Monte Carlo calculation using ALF software package [3] on two-dimensional Hubbard model with $t' = -0.3t$ at various filling, where we optimized the imaginary time dependent Hubbard U, i. e. $U(\tau)$ in the projection operator. Our results shows VAFQMC as a reliable and promising tool to simulate many-body physics in the presence of sign-problem.

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Impact of Electron Correlations on Two-Particle Charge Response in Electron- and Hole-Doped Cuprates

L. Zinni[1], **A. Nag**[2,3], **S. M. Hayden**[4], **M. Bejas**[5], **H. Yamase**[6], **J. Fink**[7,8], **A. Greco**[5], **and K.-J. Zhou**[2]

[1]Facultad de Ciencias Exactas, Ingeniería y Agrimensura, UNR-CONICET, Argentina
[2]Diamond Light Source, Harwell Campus, United Kingdom
[3]SwissFEL, Paul Scherrer Institute, Switzerland
[4]H. H. Wills Physics Laboratory, University of Bristol, United Kingdom
[5]Facultad de Ciencias Exactas, Ingeniería y Agrimensura and Instituto de Física Rosario, UNR-CONICET, Argentina
[6]Research Center for Materials Nanoarchitectonics (MANA), NIMS, Japan
[7]Leibniz Institute for Solid State and Materials Research Dresden, Germany
[8]Institut für Festkörperphysik, Technische Universität, Dresden, Germany

The existence of acoustic plasmons in high-temperature cuprate superconductors has been less extensively studied compared to conventional systems [1–3] and has generated significant debate in recent years, even evoking holographic theories from string theory [4–6]. Recent resonant inelastic x-ray scattering (RIXS) studies have now unambiguously confirmed the existence of acoustic plasmons in both hole- and electron-doped cuprates [7, 8]. The plasmon dispersion and properties (including the plasmon gap and plasma frequency behavior in the underdoped regime) have been systematically described using a large-N expansion of the layered t-J-V model [9]. While these results support the t-J-V model's applicability to cuprate plasmons, a debate persists about whether the conventional random phase approximation (RPA) adequately captures RIXS measurements. From a theoretical viewpoint, this is derived from unanswered fundamental questions regarding the role of strong correlations, such as why collective excitations survive when there is a large and incoherent electron self-energy.

In this work, through detailed calculations and direct comparison with RIXS experiments on the hole-doped cuprate $La_{1.84}Sr_{0.16}CuO_4$ and the electron-doped cuprate $La_{1.84}Ce_{0.16}CuO_4$, we demonstrate that the RPA with band parameters derived from ab initio calculations alone fails to explain the observed acoustic plasmons. We show that an effective mass must be introduced to reconcile theory with experimental observations. This mass renormalization, naturally incorporated within the t-J-V model, reveals that plasmons carry signature information about strong correlations in cuprates. Furthermore, we establish that while RPA with bare band parameters might approximate experimental plasmons in the long wavelength limit, the resulting dispersion is physically unrealistic. Only when an effective mass is properly accounted for we obtain physically consistent results. Our analysis confirms that this conclusion holds universally across both hole- and electron-doped cuprate systems.

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Stable Fermi-liquid-like phase in Lightly Doped Kagome-Lattice t-J model

Xu-Yan Jia[1], **Shou-Shu Gong**[2,3], **and D. N. Sheng**[4]

[1]*School of Physics, Beihang University, Beijing 100191, China*
[2]*School of Physical Sciences, Great Bay University, Dongguan 523000, China*
[3]*Great Bay Institute for Advanced Study, Dongguan 523000, China*
[4]*Department of Physics and Astronomy, California State University Northridge, Northridge, California 91330, USA*

Understanding the origin of superconductivity in cuprates and its relation to spin liquid is a key question in condensed matter physics. To explore the possibility of superconductivity, we study the kagome-lattice t-J model with both the nearest-neighbor and next-nearest-neighbor electron hoppings and spin interactions. By using the state of-the-art density matrix renormalization group calculation with imposing charge $U(1)$ and spin $SU(2)$ symmetries on the YC6 cylinders, we establish a quantum phase diagram including two phases: a previously reported stripe charge density wave phase and a Fermi-liquid-like phase. As the ratios t_2/t_1 and J_2/J_1 increase, the charge density wave is gradually suppressed, while the amplitude of correlations enhance significantly. In the Fermi-liquid-like phase, we identify power-law decay behaviors of density correlation, single-particle Green's function, and superconductivity pairing correlation. Furthermore, the phase remains stable across a doping range of $\delta = 1/36 - 1/18$. These findings reinforce the role of next-nearest-neighbor interactions and provide a foundation for further exploration of superconductivity on the kagome lattice.

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