Invited talks

Peter Abbamonte
University of Illinois Urbana Champaign

Evidence for Pines' Demon in Sr_2RuO_4 from Momentum-Resolved EELS

The characteristic excitation of a metal is its plasmon, which is a quantized collective oscillation of its electron density. In 1965, David Pines predicted that distinct type of plasmon, dubbed a "demon," could exist in multiband metals containing more than one species of charge carrier. A demon corresponds to an out-of-phase oscillation of electrons in different bands, i.e., a modulation in the band occupancy. Demons have proven difficult to detect because they are neutral, meaning they do not couple to light, and are gapless so their excitation energy vanishes in the long-wavelength limit. In this talk I will present evidence for a demon in the multiband metal Sr_2RuO_4 from momentum-resolved electron energy-loss spectroscopy (M-EELS). The excitation is formed from electrons in the beta and gamma bands, is gapless with a velocity v = 0.5 eV*angstrom, and exhibits a critical energy of 60 meV. I will discuss how this excitation violates low-energy sum rules in Sr_2RuO_4, which is a defining property of a demon, as well as its Landau damping into the strongly interacting continuum in this material.

Eva Andrei
Rutgers University

Flat Bands and Correlated States in Two Dimensional Atomic Crystals

Stacking 2D atomic crystals to form a moiré superstructure or applying an external periodic potential, can radically change the electronic properties. In particular, it is possible to engineer conditions leading to the creation of essentially flat energy bands with non-trivial topology, where the quenched kinetic energy facilitates the emergence of correlated electronic states. This talk will highlight two examples where the electronic ground state and Fermi surface topology depend sensitively on the filling of the flat bands: twisted graphene bilayers that develop a flat band at a magic twist-angle, and buckled graphene layers in which a strain-induced periodically modulated pseudo-magnetic field creates a post-graphene material with flat electronic bands.

Shubhayu Chatterjee (remote)
University of California Berkeley

Isospin fluctuation mediated superconductivity in rhombohedral trilayer graphene

Superconductivity was recently discovered in rhombohedral trilayer graphene (RTG) in the absence of a moiré potential. The superconducting phase lies proximate to a metallic state with reduced isospin symmetry, but it remains unknown whether this is a coincidence or a key ingredient for superconductivity. Using a Hartree-Fock analysis and constraints from experiments, we will argue that the symmetry breaking is inter-valley coherent (IVC) in nature. We will consider IVC fluctuations as a possible pairing glue, and show that they lead to chiral unconventional superconductivity when the fluctuations are strong. We will further discuss how the inter-valley Hund's coupling breaks the degeneracy between spin-singlet and triplet superconductivity. Interestingly, if the normal state is spin-unpolarized, we find that a ferromagnetic Hund's coupling favors spin-singlet superconductivity, in agreement with experiments. Instead, if the normal state is spin-polarized, then IVC fluctuations lead to spin-triplet pairing.

Joseph G. Checkelsky
Department of Physics, Massachusetts Institute of Technolog

Flat Bands and Correlated Metallic States in Kagome Metals

The notion of an electronic flat band refers to a collectively degenerate set of quantum mechanical eigenstates in periodic solids. The vanishing kinetic energy of flat bands relative to the electron-electron interaction is expected to result in a variety of many-body quantum phases of matter. Here we present recent developments in realizing flat bands in transition element-based kagome metals. We will present recent experiments in which a partial filling of a flat band is associated with unusual transport and thermodynamic that recall those of strongly correlated systems. We will also comment on the potential role of band topology and prospects for using similar lattice and orbital engineering to realize new correlated metallic states.

Piers Coleman*
Center for Materials Theory, Rutgers University

Order Fractionalization: Broken symmetry meets topology

Over the past two decades, research into quantum materials has reverberated under the impact of new concepts, particularly those of topology and fractionalization. This talk will discuss the merger of these ideas. When a spin fractionalizes into a fermion, we argue that the resulting particle can hybridize or pair with mobile electrons to develop fractionalized order. The concept of "order fractionlization" enables us to extend the concept of off-diagonal order to encompass the formation of such order parameters with fractional quantum numbers, such as spinorial order [1], but requires careful consideration of the interaction of the order parameter with the emergent gauge fields of fractionalization.

A controlled illustration of this phenomenon is provided by a model which incorporates a solvable, gapless, Z2 spin liquid - the "Yao-Lee-Kitaev model" into a Kondo lattice [2]. This model explicitly exhibits order fractionalization, and in its three dimensional formulation, undergoes a transition into an order-fractionalized phase with gapless Majorana excitations, and a charge e, S=1/2 order parameter at at arbitrarily weak Kondo coupling [3]. The broader implications of these considerations for Quantum Materials will be discussed.

*Work done in collaboration with Alexei M. Tsvelik, Brookhaven National Laboratories, supported by US department of energy grants DE- SC0012704 (AMT) and DE-FG02-99ER45790 (PC).

[1] Order Fractionalization, Yashar Komijani, Anna Toth, Premala Chandra, Piers Coleman, (2018).
[2] Order Fractionalization in a Kitaev Kondo model, Alexei Tsvelik and Piers Coleman, arXiv 2112.07781, (2021).
[3] A solvable 3D Kondo lattice with a neutral Fermi surface, Piers Coleman, Aaditya Panighri and Alexei Tsvelik, (2022).

Dominic Else (remote)
Harvard University

Critical drag as the mechanism for resistivity in strange metals

I will argue that the only way to account for the observed conductivity properties of the strange metal, assuming that it persists down to zero temperature and can be realized in a clean lattice system, is to invoke a mechanism that I call "critical drag", where the coherent part of the conductivity is suppressed by critical fluctuations. The critical fluctuations must be of an order parameter that is odd under time reversal and spatial inversion symmetries, which could be related to the experimental observations of spontaneous breaking of these symmetries in the pseudogap phase of cuprates proximate to the strange metal. The results I discuss are not based on any particular theoretical model, but rather on very general arguments that should be applicable to any conceivable theory of non-Fermi liquids.

[1] Order Fractionalization, Yashar Komijani, Anna Toth, Premala Chandra, Piers Coleman, (2018).

[2] Order Fractionalization in a Kitaev Kondo model, Alexei Tsvelik and Piers Coleman, arXiv 2112.07781, (2021).

[3] A solvable 3D Kondo lattice with a neutral Fermi surface, Piers Coleman, Aaditya Panighri and Alexei Tsvelik, (2022).

Tarun Grover (remote)
UC San Diego

Simulatable models of Heavy Fermions and Kondo breakdown.

The fermion sign problem tends to stymie exploration of highly entangled phases of matter such as interacting fermions at finite density. In this talk, I will present recent progress in simulating Fermi and non-Fermi liquids in the context of Kondo lattice systems. I will also discuss analytical results on quantum criticality in related models, and a few ideas on diagnosing Kondo breakdown.

Erik van Heumen*
University of Amsterdam

Disentangling carrier density and momentum relaxation in cuprate superconductors

One of the key mysteries in the cuprate phase diagram is the strange metallic phase, which features a variety of anomalous electronic properties. In recent years, various (magneto-) transport experiments have reported a singular behavior of the carrier density near a critical doping and these results have been interpreted as essential features of the strange metal response.
I will review these results in light of the doping evolution of the optical conductivity across the phase diagram for the single layer material Bi2201. Whereas transport experiments only probe a combination of momentum relaxation and carrier density, the optical response enables us to disentangle the two. I will show that the doping and temperature evolution of the resistivity can be fully understood from changes in the momentum relaxation rate. At the same time, the carrier density displays a continuous and gradual evolution n ~ p across the phase diagram.

*Work done in collaboration with Xuanbo Feng, Maarten Berben, Silvia Cassanelli, Lennart de Jager, Linda Neubrand, Takeshi Kondo, Tsunehiro Takeuchi, Jan Zaanen

Haoyu Hu
Rice University

Unconventional Superconductivity from Fermi Surface Fluctuations in Strongly Correlated Metals

In quantum materials, electrons that have strong correlations tend to localize, leading to quantum spins as the building blocks for low-energy physics. When strongly correlated electrons coexist with more weakly-correlated conductionelectrons, multiple channels of effective interactions develop and compete with each other. The competition creates quantum fluctuations having a large spectral weight, with the associated entropies reaching significant fractions of (R ln2) per electron. Advancing a framework to understand how the fluctuating local moments influence unconventional superconductivity is both pressing and challenging. Here we report the work [1] along this direction in the exemplary setting of heavy-fermion metals, where the amplified quantum fluctuations manifest in the form of Kondo destruction and large-to-small Fermi-surface fluctuations. These fluctuations lead to unconventional superconductivity whose transition temperature is exceptionally high relative to the effective Fermi temperature, reaching several percent of the Kondo temperature scale. Our results provide a natural understanding of the enigmatic superconductivity in a host of heavy-fermion metals. Moreover, the qualitative physics underlying our findings and their implications for the formation of unconventional superconductivity apply to a variety of highly correlated metals with strong Fermi surface fluctuations.

[1] Haoyu Hu, Ang Cai, Lei Chen, Lili Deng, Jed H. Pixley, Kevin Ingersent, Qimiao Si, arXiv:2109.13224 (2021).

Harold Y. Hwang (remote)
Stanford University, SLAC National Accelerator Laboratory

Superconductivity in infinite layer nickelates

Since its discovery, unconventional superconductivity in cuprates has motivated the search for materials with analogous electronic or atomic structure. We have used soft chemistry approaches to synthesize superconducting infinite layer nickelates from their perovskite precursor phase, using topotactic reactions. We will present the synthesis and transport properties of the nickelates, observation of a doping-dependent superconducting dome, and our current understanding of the electronic and magnetic structure.

Kazushi Kanoda* (remote)
Applied Physics, University of Tokyo

Superconductivity in a doped spin liquid candidate; spin-singlet nodal pairing, suppressed superfluid density and BEC-BCS crossover

Quantum spin liquid (QSL) is an issue of profound interest. Further intriguing is superconductivity that possibly emerges by doping a QSL. In this conference, I report our experimental study on the superconductivity in an organic candidate material, a 11% hole doped triangular-lattice Mott insulator. At ambient pressure, the ^{13}C NMR measurements suggest spin-singlet nodal pairing. The superfluid density evaluated by the penetration depth measurements is considerably suppressed to the level of the doped-hole density, implying the presence of incoherent spectral weight or hidden order. The transport and Nernst effect measurements show that the superconductivity at ambient pressure is a BEC-like condensate from a non-Fermi liquid and is driven to a BCS condensate from a Fermi liquid by pressure, which reduces the Coulombic interactions among electrons. This is a BEC-BCS crossover tuned by Mottness. I also present the thermoelectric signature of quantum criticality in the doped QSL phase and its possible relevance to superconductivity.

*The present work is a collaboration with Y. Suzuki, K. Wakamatsu, Y. Ueno, J. Ibuka, H. Oike, T. Fujii, K. Miyagawa and H. Taniguchi.

Eun-Ah Kim
Cornell University

Routes to T-linear resistivity

Understanding incoherent metallic states with *T*-linear resistivity seen in many strongly correlated materials remains a central question in the community. With progress in theoretical understanding in solvable models and advancements in computer simulations and physical systems designed to simulate correlated models, new insights are becoming available. Here I will present our observations of *T*-linear resistivity in different simulations and effective model calculations and compare and contrast different mechanisms at play [1-3]. The hope with the retrospection would be to gain insights that transcend individual models.

[1] Peter Cha, Nils Wentzell, Olivier Parcollet, Antoine Georges, Eun-Ah Kim, "Linear resistivity and Sachdev-Ye-Kitaev (SYK) spin liquid behavior in a quantum critical metal with spin-1/2 fermions", PNAS 117, 18341 (2020).
[2] Peter Cha, Aavishkar Patel, Eun-Ah Kim, "Slope invariant T-linear resistivity from local self-energy", Phys. Rev. Research 2,033434 (2020).
[3] Peter Cha, Aavishkar Patel, Eun-Ah Kim, "Strange Metals from Melting Correlated Insulators in Twisted Bilayer Graphene", arXiv: 2105.08069, to appear in PRL.

Yong-Baek Kim (remote)
Center for Quantum Materials, Department of Physics, University of Toronto

Non-Fermi liquids and quantum criticality in multipolar Kondo systems

We discuss emergent non-Fermi liquid behaviors in multipolar Kondo systems, where conduction electrons interact with the non-Kramers local moments that carry higher-rank multipolar moments such as quadrupolar and octupolar moments. We first show that unexpected non-Fermi liquid states arise in the single impurity multipolar Kondo system using the renormalization group and conformal field theory. Next, we study the competition between the Kondo and RKKY interactions in the Bose-Fermi Kondo systems, where the RKKY interaction between multipolar moments is represented by a bosonic degree of freedom. We present the renormalization group solution of this problem and describe the quantum critical behaviors. If time permits, we also discuss possible superconducting states arising from the multipolar Kondo interactions. We compare the theoretical results with existing experimental data on some cubic f-electron systems.

Steven A. Kivelson
Stanford University

Superconductivity in the Hubbard Model

Since the discovery of high temperature superconductivity in the cuprates, much of the discussion concerning the mechanism of unconventional superconductivity in these (and other) materials has involved stories about the behavior of the Hubbard model. Real materials are complicated, with observable behaviors that are sensitive to all sorts of microscopic details, leading to debates over what is *essential* and what is a *herring* of one color or another. However, as a theoretical minimum, conditions for the existence of superconductivity in the Hubbard model can be addressed seriously, using tools that are controlled and unambiguous in appropriate limits. While it is easy to show that the ground-state is generically superconducting for small U, at intermediate U (which is a necessary condition for “high temperature superconductivity”) the answer is much more complicated as superconductivity competes and more generally “intertwines” with various forms of density-wave order. Still there are some interesting corners of the phase diagram where superconductivity occurs – even at intermediate coupling.

Anaëlle Legros (remote)
Johns Hopkins University

Observation of cyclotron resonance and measurement of the cyclotron mass in $La_{2-x}Sr_xCuO_4$

Using recently developed time-domain terahertz spectroscopy in pulsed magnetic fields, we measure the complex optical conductivity of LSCO thin films up to 31 T. This work reveals a cyclotron resonance consistent with the cyclotron motion of holes with a mass of 4.9±0.8 m_e for the optimally doped sample. Studying this quantity as a function of doping in overdoped samples shows an increase of the mass with doping up to samples close to the end of the superconducting dome. The scattering rate can also be extracted and is found to increase with magnetic field, in the same way as the measured magnetoresistance. This new technique opens the path towards the study of crucial quantities in strongly correlated metals with less stringent requirements than quantum oscillation measurements.

Karyn Le Hur
CPHT, CNRS, Ecole Polytechnique, Institut Polytechnique de Paris

Curved Space Topometry and Fractional Entangled Bloch Bands applied to Semimetals

Topological spaces have numerous applications for quantum matter with protected chiral edge modes related to an integer-valued Chern number, which also characterizes the global response of a spin-1/2 particle to a magnetic field. Such spin-1/2 models can also describe topological Bloch bands in lattice Hamiltonians. Here, we introduce interactions in a system of spin-1/2s to reveal a class of topological states with rational-valued Chern numbers for each spin providing a geometrical and physical interpretation related to curvatures and quantum entanglement via smooth fields. We study a driving protocol in time to reveal the stability of the fractional topological numbers towards various forms of interactions in the adiabatic limit. We elucidate a correspondence of a one-half topological spin response in bilayer semimetals on a honeycomb lattice with a nodal ring at one Dirac point and a robust pi-Berry phase at the other Dirac point. We also discuss applications for superconductivity. The geometrical description also allows applications in quantum transport and light including interactions.

- Joel Hutchinson and Karyn Le Hur, Communications Physics 1, 144 (2021), Nature Journal
- Karyn Le Hur, arXiv:2106.15665
- Joel Hutchinson, Philipp W. Klein, Karyn Le Hur Phys. Rev. B 104, 075120 (2021)
- Philipp W. Klein, Adolfo Grushin, Karyn Le Hur, Phys. Rev. B 103, 035114 (2021)
- Peng Cheng, Philipp W. Klein, Kirill Plekhanov, Klaus Sengstock, Monika Aidelsburger, Christoph Weitenberg, Karyn Le Hur, Phys. Rev. B 100, 081107 (2019)

Abhay Pasupathy
Columbia University

Quantum criticality in twisted WSe_2

In this talk, I will describe experiments on gate-tunable metal-insulator transitions in moiré heterostructures. In these materials, insulating phases driven by electronic correlations have been recently discovered near half-filling of the first moiré subband. In our experiments on twisted WSe_2 bilayers, we find that the metal-insulator transition as a function of both density and displacement field is continuous. At the metal-insulator boundary, the resistivity displays strange metal behaviour at low temperature with dissipation comparable to the Planckian limit. Further into the metallic phase, Fermi-liquid behaviour is recovered at low temperature which evolves into a quantum critical fan at intermediate temperatures before eventually reaching an anomalous saturated regime near room temperature. An analysis of the residual resistivity indicates the presence of strong quantum fluctuations in the insulating phase. These results establish twisted WSe_2 as a new platform to study doping and bandwidth controlled metal-insulator quantum phase transitions on the triangular lattice.

References:
Wang et al, Nature Materials 19, 861–866 (2020) Ghiotto et al, Nature 597, 345–349 (2021)

Aavishkar Patel
University of California Berkeley

Strange metals: quantum criticality, disordered interactions, Planckian dissipation, and scale invariance

I will describe new models that can systematically describe strange metals at quantum critical points, and that allow for the accurate computation of a whole host of experimentally measurable static and dynamic quantities despite the presence of both strong correlations and disorder. I will demonstrate that disorder can couple to interaction operators, leading to the experimentally observed linear-in-temperature (*T*-linear) resistivity seen at metallic quantum critical points, a *T ln T* specific heat, and also the observed universal “Planckian” transport scattering rate of $k_B T/\hbar$. Finally, I will show that “perfect” *T*-linear resistivity is associated with an energy invariant quantity defined in the many-body microcanonical ensemble, which motivates the existence of a deep connection between the "bad metal" *T*-linear resistivity seen at high temperatures and the "good metal" *T*-linear resistivity seen at low temperatures with the same slope in many quantum critical materials.

Catherine Pepin (remote)
CEA Saclay

Charge orders and strange metals in cuprate superconductors

Charge orders and charge fluctuations have been ubiquitously observed in the phase diagram of Cuprate superconductors. We will review the experimental status of these various observations, differentiating the under-doped region and the optimally-doped and over-doped ones. Various theories have been advanced to explain the presence of these orders and their implication for our understanding of the pseudo-gap, from the idea of “vestigial order” to the one of “fluctuating Pair Density Wave (PDW)”. We will discuss these theoretical approaches in direct comparison with experiments. We will then introduce a proposal of “fractionalization of a PDW” in order to explain the pseudo-gap state. We will show that this idea produces a strong phenomenology, especially ARPES experiments, and giving a clue for the puzzling transport properties recently reported in the optimally doped and over-doped regions. We will then focus on the strange metal phase of those compounds and make a proposal for electric transport in this phase.

Philip W. Phillips
University of Illinois Urbana Champaign

Beyond BCS: An Exact Model for Superconductivity and Mottness

High-temperature superconductivity in the cuprates remains an unsolved problem because the cuprates start off their lives as Mott insulators in which no apparent organizing principle such a Fermi surface can be invoked to treat the electron interactions. The natural question arises: What is the simplest tractable model for a non-Fermi liquid and does this model describe a Mott insulator? Because Fermi liquids are inherently non-interacting states of matter, the simplest way forward is to engineer a model in which some of the states are singly occupied below the chemical potential. We show that breaking an overlooked local-in-momentum space Z_2 symmetry of a Fermi liquid does precisely this. This symmetry breaking serves as an organizing principle for Mott physics whether it arises from the tractable Hatsugai-Kohmoto or Hubbard models. That is, both are controlled by the same quartic fixed point. We then show exactly [2] that this fixed point is unstable to a weak pairing interaction and hence exhibits the analogue of Cooper's instability. The properties of the superconducting state differ drastically [3] from that of the standard BCS theory. The elementary excitations of this superconductor are not linear combinations of particle and hole states but rather are superpositions of doublons and holons, composite excitations signaling that the superconducting ground state of the doped Mott insulator inherits the non-Fermi liquid character of the normal state. Additionally, the gap turns on at a temperature above which the pair susceptibility diverges, strong correlations of the Mott state kill the Hebel-Slichter peak and this model exhibits a superconductivity-induced transfer of spectral weight from high to low energies and a suppression of the superfluid density as seen in the cuprates. As several of these properties are observed in the cuprates, our analysis here points a way forward in computing the superconducting properties of strongly correlated electron matter.

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[2] PWP, L. Yeo, E. Huang, Nature Physics, 16, 1175-1180 (2020).
[3] J. Zhao, L. Yeo, E. Huang, PWP, https://arxiv.org/abs/2111.14852.

Jed H. Pixley
Department of Physics and Astronomy, Center for Materials Theory, Rutgers University

Twisting nodal superconductors

The realization of correlated insulators and superconductivity in twisted van der Waals heterostructures has brought forth twisting as a new control knob in condensed matter laboratories. In this talk we will show how twisting can be used to control the low energy physics of bilayers of nodal superconductors. Focusing in the vicinity of the Dirac nodes in their Bogolioubov de Gennes (BdG) spectrum we demonstrate that in the limit of small twists the BdG velocity vanishes at a magic-angle, which we estimate for a few nodal superconductors that are available in monolayer form. At the magic-angle the effects of the interactions between the BdG quasiparticles are greatly enhanced leading to a secondary, time reversal breaking, superconducting instability. In addition, we demonstrate that applying an interlayer current to twisted nodal superconductors at any (small) twist angle induces a topological superconducting state. Last, recent experiments have successfully twisted thin slabs of BSCCO while maintaining the high temperature superconducting state. The results on the critical current and related Josephson effects for a wide range of twist angles will be presented that demonstrates an observation of the second harmonic in the current phase relationship for a twist of 45 degrees.

Priscila F. S. Rosa
Los Alamos National Laboratory, Los Alamos

Unraveling the superconducting state of UTe_2

Spin-triplet superconductors are a promising route in the search for topological superconductivity, and UTe_2 is a recently discovered contender. In this talk, I will present a brief overview of key experimental results on the superconducting state of UTe_2 as well as some of its outstanding puzzles. I will then focus on recent developments in sample synthesis combined with thermodynamic measurements that shed light on the role of disorder and magnetic fluctuations in UTe_2. At the end of the talk, I will highlight some of the pressing outstanding open questions regarding the superconducting order parameter of UTe_2.

Subir Sachdev
Harvard University

Paramagnon fractionalization theory of the pseudogap metal of the cuprates

We examine the spectral properties of a recently proposed theory of the intermediate temperature pseudogap metal phase of the cuprates. We show that this theory can be obtained from the familiar paramagnon theory of nearly antiferromagnetic metals by fractionalizing the paramagnon into two `hidden' layers of S=1/2 spins. The first hidden layer of spins hybridizes with the electrons as in a Kondo lattice heavy Fermi liquid, while the second hidden layer of spins forms a spin liquid with fractionalized spinon excitations. We compute the imaginary part of the electronic self energy induced by the spinon excitations. The energy and momentum dependence of the photoemission spectrum across the Brillouin zone provides a good match to observations by He et al. in Bi2201 (Science 331, 1579 (2011)) and by Chen et al. in Bi2212 (Science 366, 1099 (2019)).

Ref: E. Mascot, A. Nikolaenko, M. Tikhanovskaya, Ya-Hui Zhang, D. K. Morr, and S. Sachdev, arXiv:2111.13703

Qimiao Si
Department of Physics & Astronomy, Rice Center for Quantum Materials, Rice University

Quantum criticality in strongly correlated metals

A prevailing issue on quantum criticality, especially for strongly correlated metals, is whether and how it goes beyond the Landau framework of order-parameter fluctuations. In the context of antiferromagnetic heavy fermion metals, the notion of Kondo destruction has been developed to address the issue [1]. A defining characteristic across a Kondo-destruction quantum critical point is a sudden transformation of the Fermi surface from "large" to "small". In this context, I'll address the charge dynamics [2,3] and entanglement properties [4] near the quantum critical point, and demonstrate how they drive unconventional superconductivity of high-T_c (i.e., T_c reaching a few percent of the effective Fermi temperature) [5]. Connections with the localization-delocalization physics of other strongly correlated electron systems will be discussed.

[1] S. Paschen & Q. Si, Nat. Rev. Phys. 3, 9 (2021); S. Kirchner et al, Rev. Mod. Phys. 92, 011002 (2020); Q. Si, S. Rabello, K. Ingersent, and J. L. Smith, Nature 413, 804 (2001).
[2] L. Prochaska, X. Li, D. C. MacFarland, A. M. Andrews, M. Bonta, E. F. Bianco, S. Yazdi, W. Schrenk, H. Detz, A. Limbeck, Q. Si, E. Ringe, G. Strasser, J. Kono, S. Paschen, Science 367, 285 (2020).
[3] A. Cai, Z. Yu, H. Hu, S. Kirchner, Q. Si, Phys. Rev. Lett. 124, 027205 (2020); L. J. Zhu, S. Kirchner, Q. Si, A. Georges, Phys. Rev. Lett. 93, 267201 (2004).
[4] H. Hu, A. Cai, Q. Si, arXiv:2004.04679 (2020).
[5] H. Hu, A. Cai, L. Chen, L. Deng, J. H. Pixley, K. Ingersent, Q. Si, arXiv:2109.13224.

Mathieu Taupin
Institute of Solid State Physics, TU Wien

Extreme strange metal behavior in the unconventional superconductor $YbRh_2Si_2$

The heavy fermion compound $YbRh_2Si_2$ is an excellent platform to study quantum criticality [1]. For example, it was used to demonstrate a jump in the Fermi surface volume at its magnetic field-induced quantum critical point (QCP) [2], as well as dynamical energy-over-temperature scaling in the THz conductivity [3]. Most recently, using sub-millikelvin electrical resistivity measurements, superconductivity – previously seen away from the QCP [4] – was found to condense directly out of the material's extreme strange metal state, which extends over 3.5 orders of magnitude in temperature [5]. We also investigate the relation between the strange metal behavior and Planckian dissipation, both in $YbRh_2Si_2$ and in other heavy fermion compounds [6].

[1] S. Paschen and Q. Si, Nat. Rev. Phys. 3, 9 (2021).
[2] S. Paschen et al., Nature 432, 881 (2004); S. Friedemann et al., PNAS 107, 14547 (2010).
[3] L. Prochaska et al., Science 367, 285 (2020).
[4] E. Schubert et al., Science 351, 485 (2016).
[5] D. H. Nguyen et al., Nat. Commun. 12, 4341 (2021). Featured article, https://www.nature.com/collections/rcdhyvxytb (Aug 11, 2021).
[6] M. Taupin and S. Paschen, *arXiv:2201.02820* (2022).

Nandini Trivedi* (remote)
Ohio State University

New topological phases in the Kitaev model as a function of magnetic field

The Kitaev model with anisotropic interactions on the bonds of a honeycomb lattice is a paradigmatic model for quantum spin liquids. Despite the simplicity of the model, a rich phase diagram with gapless and gapped quantum spin liquid phases, with abelian and non-abelian excitations, are revealed as a function of a magnetic field and bond couplings. Our results of the entanglement entropy, topological entanglement entropy, and the dynamical spin excitation spectrum, are obtained using exact diagonalization and density matrix renormalization group (DMRG) methods. We provide insights into the phases from the underlying effective field theories.

*In collaboration with Shi Feng, Cullen Gantenberg, Adhip Agarwala, Sandip Trivedi, Subhro Bhattacharjee

[1] Signatures of magnetic-field-driven quantum phase transitions in the entanglement entropy and spin dynamics of the Kitaev honeycomb model, David C. Ronquillo, Adu Vengal, Nandini Trivedi, Phys. Rev. B 99, 140413 (2019).
[2] Magnetic field induced intermediate quantum spin-liquid with a spinon Fermi surface, Niravkumar D. Patel and Nandini Trivedi, Proceedings of the National Academy of Sciences 116, 12199 (2019).
[3] Two-Magnon Bound States in the Kitaev Model in a [111]-Field, Subhasree Pradhan, Niravkumar D. Patel, Nandini Trivedi, Phys. Rev. B 101, 180401 (2020).
[4] Symmetry Analysis of Tensors in the Honeycomb Lattice of Edge-Sharing Octahedra, Franz G. Utermohlen, Nandini Trivedi, Phys. Rev. B 103, 155124 (2021).

Stephen Wilson
University of California, Santa Barbara

New classes of topological kagome metals and their unusual electronic properties

Kagome metals are compelling materials platforms for hosting electronic states that feature an interplay between topologically nontrivial electronic states and correlated electron phenomena. These two features can, for instance, arise from the Dirac points, flatbands, and saddle-points endemic to the kagome lattice type in simple tight-binding models. In this talk I will present some of our recent work exploring the electronic properties of two new classes of kagome metals, each with Z2 topology and saddle points close to Fermi energy. Specifically, our work studying the compounds AV_3Sb_5 (A=K, Cs, Rb) and RV_6Sn_6 (R=rare earth ion) will be presented. The former family of compounds exhibit an unusual charge density wave order intertwined with a low temperature superconducting ground state, and the latter family provide a tunable platform for interfacing magnetic order with a topologically nontrivial kagome band structure. Unconventional electronic properties observed in each class of new kagome compunds and open questions will be discussed.

Mengxing Ye
University of California Santa Barbara

Pseudogap formation due to spin-density-wave fluctuations at finite temperature

The pseudogap behavior, observed in several classes of materials, most notably high Tc cuprates, remains one of the most debated phenomena in correlated electron systems. In the past few years, there have been significant numerical advances which suggest an important role of spin fluctuations in pseudogap formation at finite temperature. In this talk, I propose a minimal analytical model that can capture the essential features observed numerically. I will explain how the electrons remain a dynamical memory about the underlying order in some temperature range even if the order is already destroyed by thermal fluctuations. I will further show that the Heisenberg-spin like feature of magnetic fluctuations can be self-consistently obtained from this itinerant electron perspective. Generalizations to other lattice systems and new physics will also be discussed.

Ming Yi
Rice University

Correlation-Driven Electronic Reconstruction in Iron-Chalcogenides

Electronic correlation is of fundamental importance to high temperature superconductivity. While the low energy electronic states in cuprates are dominantly affected by correlation effects across the phase diagram, observation of correlation-driven changes in fermiology amongst the iron-based superconductors remains rare. Here we present experimental evidence for a correlation-driven reconstruction of the Fermi surface tuned independently by two orthogonal axes of temperature and Se/Te ratio in the iron chalcogenide materials. We demonstrate that this reconstruction is driven by the de-hybridization of a strongly renormalized d_{xy} orbital with the remaining itinerant iron 3d orbitals in the emergence of an orbital-selective Mott phase. Our observations are further supported by our theoretical calculations to be salient spectroscopic signatures of such a non-thermal evolution from a strongly correlated metallic phase into an orbital-selective Mott phase in d_{xy} as Se concentration is reduced.

Contributed talks

(S1: Tuesday, S2: Thursday)

Mitchell Bordelon (S1-1)
Los Alamos National Laboratory

Unusual magnetism and field-induced transitions in Cerium-based materials

Magnetic frustration is a promising route toward realizing new phases of matter with exotic physical properties. In lanthanide-based materials, frustration can arise due to the geometric arrangement of moments, magnetocrystalline anisotropy from the interplay of spin-orbit coupling (SOC) and crystalline electric field (CEF) effects, Kondo behavior, and conduction electron mediated Ruderman-Kittel-Kasuya-Yosida (RKKY) exchange interactions. Here, we report on three trivalent Ce materials with magnetically frustrated ground states: $CeLiBi_2$, $CeLi_3Bi_2$, and $CeLi_3Sb_2$. The first material, $CeLiBi_2$, is a newly discovered, highly conductive tetragonal antiferromagnet (P4/nmm), while the latter two are insulating triangular lattice Zintl phases (P-3m1) with antiferromagnetic ($CeLi_3Bi_2$) and ferromagnetic ($CeLi_3Sb_2$) ground states. In $CeLiBi_2$, the CEF ground state naively predicts dominant ferromagnetic interactions that starkly contrasts the antiferromagnetic signatures in specific heat, magnetic susceptibility, and thermal expansion measurements. Additionally, $CeLiBi_2$ displays multiple metamagnetic transitions below T_N = 3.4 K, large anomalous Hall conductivity, and strain amplified quantum oscillations. In $CeLi_3(Sb,Bi)_2$, geometrical frustration of localized Ce moments on a triangular lattice leads to two disparate magnetic ground states despite similarities in chemical species and crystal structure. Both materials contain in-plane Ce moments, and $CeLi_3Bi_2$ orders below T_N = 1.1 K while $CeLi_3Sb_2$ orders at T_C = 5 K.

Areg Ghazaryan (S2-1)
IST Austria

Unconventional Superconductivity in Rhombohedral Trilayer Graphene

In this talk I will show that in a two-dimensional electron gas with an annular Fermi surface, long-range Coulomb interactions can lead to unconventional superconductivity by the Kohn-Luttinger mechanism. Superconductivity is strongly enhanced when the inner and outer Fermi surfaces are close to each other. The most prevalent state has chiral p-wave symmetry, but d-wave and extended s-wave pairing are also possible. I will discuss these results in the context of rhombohedral trilayer graphene, where superconductivity was recently discovered in regimes where the normal state has an annular Fermi surface. The theory naturally explains some of the outstanding puzzles in this material, that include the weak temperature dependence of the resistivity above critical temperature and the proximity of spin singlet superconductivity to the ferromagnetic phase.

Blaise Goutéraux (S1-2)
Ecole Polytechnique

Damping of pseudo-Goldstones and application to strange metallic transport

In the presence of a source of weak explicit breaking, Goldstone modes arising from the spontaneous breaking of the same symmetry become massive. I will explain that locality of the resulting effective theory implies that they also acquire a lifetime, which is completely determined by their mass and a diffusion constant of the unrelaxed theory. I will also discuss how these results can be applied to strange metallic transport in the presence of charge density wave fluctuations.

Yi-Ting Hsu (S2-2)
University of Notre Dame

Higher-order topological superconductivity: material predictions enabled by boundary-diagnosing invariants

Majorana corner modes can only exist in topological superconductors protected by certain crystalline symmetries. In this talk, I will show that inversion-symmetric WTe_2 is a promising candidate hosting corner Majoranas. Instead of model-dependent coincidence, monolayer WTe_2 in fact satisfies a general recipe for inversion-protected higher-order superconductors. This recipe is derived from topological invariants that can diagnose the real-space Majorana boundary type from band structures. Such boundary diagnostics for different wallpaper groups, including cases beyond symmetry indicators, can enable systematic searches in material databases for topological superconductors with Majorana edge and corner modes.

Alex Levchenko* (S1-3)
University of Wisconsin Madison

Thermodynamic properties of nodal superconductors near magnetic quantum critical point

In this work we study thermodynamic manifestations of the quantum criticality in multiband unconventional superconductors. As a guiding example we consider the scenario of magnetic quantum critical point in the model that captures superconductivity coexistence with the spin-density wave. We show that in situations when superconducting order parameter has incidental nodes at isolated points, quantum magnetic fluctuations lead to the renormalization of the relative T-linear slope of the London penetration depth. This leads to the nonmonotonic dependence of the penetration depth as a function of doping and the concomitant peak structure across the quantum critical point. In addition, we determine contribution of magnetic fluctuations to the specific heat at the onset of coexistence phase. Our theoretical analysis is corroborated by making a comparison of our results with the recent experimental data from the low-temperature thermodynamic measurements at optimal composition in $BaFe_2(As_{1-x}P_x)_2$.

*Work done in collaboration with Jaglul Hasan, Maxim Dzero, Maxim Khodas.

Peter Lunts (S1-4)
University of Maryland

The hot spot model via Hamiltonian Monte Carlo

The hot spot model is a low energy model describing the itinerant quantum phase transition to an antiferromagnetically ordered state. We numerically study a sign-problem-free version of the hot spot model using a Hamiltonian Monte Carlo (HMC) algorithm. Compared to the standard Determinantal Quantum Monte Carlo, HMC offers a superior scaling in system size. Together with new additional algorithmic improvements, this allows us to reach system sizes that are several times larger than those considered in previous studies. We use our method to study the critical momentum scaling of key observables in the small momentum limit. We comment on our findings in the context of various existing analytical results.

Pavel Volkov (S2-4)
Rutgers University

Magnetic field-induced topological domains in twisted nodal superconductors

Twisted bilayers of nodal superconductors are promising platforms for the realization of topological superconductivity, that can be generated by driving a current between layers. I will demonstrate that, in addition to that, the application of an in-plane magnetic field creates topological domains with alternating Chern number. The size of the domains can be controlled by field strength and the low-energy spectrum is formed from the chiral edge modes at the domain boundaries, leading to experimentally observable signatures.

Ashley Weiland (S2-3) - cancelled
Los Alamos National Laboratory, Los Alamos

A crystallographic study of UTe_2

The spin-triplet candidate superconductor UTe_2 [1] crystallizes in the Immm space group (no. 71), a = ~4.16 Å, b = ~6.14 Å, and c = ~13.98 Å, and contains three crystallographic sites, one U site which occupies the 4i position and two Te sites, where Te1 occupies the 4j position and Te2 occupies the 4h position [2]. An intrinsic multicomponent superconducting order parameter has been suggested to exist in UTe_2 [3] although contrasting reports indicate that the dual transitions arise due to inhomogeneity within the crystal [4]. This talk will focus on detailed single crystal X-ray diffraction studies to probe crystallographic differences in samples with double or single superconducting transitions to elucidate their origin.

[1] S. Ran et al. Science 365, 684 (2019)
[2] A. J. K. Haneveld et al. J. Less-Common Met. 21, 45 (1970)
[3] I. M. Hayes et al. Science 373, 797 (2021)
[4] L. P. Cairns et al. J. Phys.: Condens. Matter 32, 415602 (2020); S. M. Thomas et al. arXiv:2103.09194 (2021); P.F.S. Rosa et al. ArXiv:2110.06200 (2021)

Posters

Peter Cha
Cornell University

Strange metals from melting correlated insulators in twisted bilayer graphene

Even as the understanding of the mechanism behind correlated insulating states in magic-angle twisted bilayer graphene converges towards various kinds of spontaneous symmetry breaking, the metallic "normal state" above the insulating transition temperature remains mysterious, with its excessively high entropy and linear-in-temperature resistivity. In this work, we focus on the effects of fluctuations of the order-parameters describing correlated insulating states at integer fillings of the low-energy flat bands on charge transport. Motivated by the observation of heterogeneity in the order-parameter landscape at zero magnetic field in certain samples, we conjecture the existence of frustrating extended range interactions in an effective Ising model of the order-parameters on a triangular lattice. The competition between short-distance ferromagnetic interactions and frustrating extended range antiferromagnetic interactions leads to an emergent length scale that forms stripe-like mesoscale domains above the ordering transition. The gapless fluctuations of these heterogeneous configurations are found to be responsible for the linear-in-temperature resistivity as well as the enhanced low temperature entropy. Our insights link experimentally observed linear-in-temperature resistivity and enhanced entropy to the strength of frustration, or equivalently, to the emergence of mesoscopic length scales characterizing order-parameter domains.

Lei Chen
Department of Physics and Astronomy, Rice Center for Quantum Materials, Rice University

Multiorbital spin-triplet pairing and spin resonance in the heavy-fermion superconductor UTe_2

The heavy-fermion system UTe_2 is a candidate for spin-triplet superconductivity, which is of considerable interest to quantum engineering. Among the outstanding issues is the nature of the pairing state. A recent surprising discovery is the observation of a resonance in the spin excitation spectrum at an antiferromagnetic (AFM) wavevector [1], which stands in apparent contrast to the ferromagnetic (FM) nature of the interactions expected in this system. In this work [2], we show how the puzzle can be resolved by a multiorbital spin-triplet pairing constructed from local degrees of freedom. We construct a model with both FM and AFM exchange interactions, which successfully captures the AFM magnetic fluctuations observed by the inelastic neutron scattering. The triplet pairing field between the two U sublattices, which takes a matrix form in both spin and orbital spaces, is stabilized by inter-sublattice FM interactions. Combining this spin-triplet pairing state and AF fluctuations, we demonstrate the existence of spin resonance at AF wavevector through a calculation of dynamical spin susceptibility. Our work illustrates how orbital degrees of freedom can enrich the nature and properties of spin-triplet superconductivity of strongly-correlated quantum materials.

[1] C. Duan et al., Nature 600, 636 (2021).
[2] L. Chen et al., arXiv: 2112.14750.

*Work done in collaboration with Haoyu Hu, Christopher Lane, Emilian M. Nica, Jian-Xin Zhu, Qimiao Si

Yang Ge
University of Cincinnati

Emergent Spinon Dispersion and Symmetry Breaking in Two-channel Kondo Lattices

Two-channel Kondo lattice serves as a model for a growing family of heavy-fermion compounds. We employ dynamical large-N technique and go beyond the independent bath approximation to study this model both numerically and analytically using renormalization group ideas. We show that Kondo effect induces dynamic magnetic correlations that lead to an emergent spinon dispersion. Furthermore, we develop a quantitative framework that interpolates between infinite dimension where the channel-symmetry broken results of mean-field theory are confirmed, and one-dimension where the channel symmetry is restored and a critical fractionalized mode is found.

Augusto Ghiotto
Columbia University

Quantum criticality in twisted transition metal dichalcogenides

Here, we use transport measurements to characterize metal–insulator transitions (MITs) in twisted WSe_2 near half filling of the first moiré subband. We find that the MIT as a function of both density and displacement field is continuous. At the metal–insulator boundary, the resistivity displays strange metal behavior at low temperatures, with dissipation comparable to that at the Planckian limit. Further into the metallic phase, Fermi liquid behavior is recovered at low temperature, and this evolves into a quantum critical fan at intermediate temperatures, before eventually reaching an anomalous saturated regime near room temperature. An analysis of the residual resistivity indicates the presence of strong quantum fluctuations in the insulating phase. These results establish twisted WSe_2 as a new platform to study doping and bandwidth-controlled metal–insulator quantum phase transitions on the triangular lattice.

Clement Girod
Los Alamos National Laboratory

Mapping the superconducting phase of UTe_2 under uniaxial stress

The recently discovered uranium-based unconventional superconductor UTe_2 has attracted attention as a promising candidate for spin-triplet pairing and topological superconductivity. Among its numerous peculiarities, UTe_2 hosts different superconducting phases as a function of applied hydrostatic pressure and magnetic fields. For hydrostatic pressures exceeding 0.3 GPa, UTe_2 exhibits two superconducting transitions that have opposite pressure dependence. At zero field and ambient pressure, UTe_2 crystals with an optimal superconducting transition temperature, T_c = 2 K, host a single thermodynamic superconducting transition. Some reports, however, argue that a multi- component order parameter exists even at ambient pressure. Due to its orthorhombic structure symmetry, any multi-component order parameter should lead to two non-degenerate superconducting transitions in UTe_2. The reason multiple transitions are not observed below P = 0.3 GPa in the highest quality crystals remains unknown, as does the sudden emergence of two transitions at P = 0.3 GPa. Here, we investigate the uniaxial stress dependence of the low temperature specific heat and electrical resistivity of UTe_2 along different crystallographic directions to better understand the pressure- temperature phase diagram of UTe_2.

Tamaghna Hazra*
Rutgers University

Triplet pairing via Kondo hybridization - applications to UTe_2 and $CeRh_2As_2$

Abstract: We explore a pairing mechanism for triplet superconductivity mediated by Kondo interactions, relevant for UTe_2 and $CeRh_2As_2$. In these systems, the upper critical field violates the Pauli limit by an order of magnitude, and there are multiple distinct superconducting phases which appear to be enhanced and even enabled by strong magnetic fields. We review the outstanding experimental puzzles in these materials, such as the evidence for time-reversal breaking superconductivity and chiral edge modes in UTe_2 and multi-phase superconductivity pre-empted by a mysterious second-order phase transition in $CeRh_2As_2$. Taken together, these puzzles challenge our current understanding of heavy fermion superconductivity and raise the intriguing possibility of a very new kind of superconductivity driven by the local moments of U and Ce, which harbour Hunds-coupled pre-formed triplet pairs. We seek to unify the Kondo physics with the triplet pairing in a coherent framework. With this motivation, we present a mean-field analysis of a simple two-channel Kondo model which has two spins at locally-noncentrosymmetric sites in the unit cell, inspired by UTe_2 and $CeRh_2As_2$, which illustrates the emergence of local triplet correlations as a result of Kondo hybridization with Hunds-coupled local moments. In the spirit of a resonating valence bond picture, the superconductivity can be understood as the condensation of local spin-triplet pre-formed pairs which are odd under exchange of the two U/Ce sites.

*Work done in collaboration with Piers Coleman.

Yi-Ting Hsu
University of Notre Dame

Higher-order topological superconductivity: material predictions enabled by boundary-diagnosing invariants

Majorana corner modes can only exist in topological superconductors protected by certain crystalline symmetries. In this talk, I will show that inversion-symmetric WTe_2 is a promising candidate hosting corner Majoranas. Instead of model-dependent coincidence, monolayer WTe_2 in fact satisfies a general recipe for inversion-protected higher-order superconductors. This recipe is derived from topological invariants that can diagnose the real-space Majorana boundary type from band structures. Such boundary diagnostics for different wallpaper groups, including cases beyond symmetry indicators, can enable systematic searches in material databases for topological superconductors with Majorana edge and corner modes.

Haoyu Hu*
Rice University

Gapless electronic topology without free-electron counterpart

The interplay between interactions and topology in quantum materials is of extensive current interest. In noninteracting systems, electronic topology is described in terms of Bloch functions. However, strong interactions can invalidate the analogy with noninteracting systems by destroying well-defined Landau quasi-particles. Here, we consider a multi-channel Anderson lattice model on several lattices, where the electron correlations lead to a strange-metal phase. The space group symmetry constraints are analyzed through the eigenvectors of Green's functions. The electronic topology is characterized in terms of Hall conductivities and surface state. We demonstrate gapless topological phases without any free-electron counterpart and identify candidate materials to realize the proposed phases [1]. Our work opens a door to a variety of gapless topological phases without free-electron counterpart in a broad range of strongly correlated metals.

[1] H. Hu, et al., arXiv:2110.06182 (2021).

*Work done in collaboration with Lei Chen, Chandan Setty, Sarah E. Grefe, Andrey Prokofiev, Stefan Kirchner, Silke Paschen, Jennifer Cano, Qimiao Si

Dian Jing
Northwestern University

Mechanism of skyrmion condensation and pairing for twisted bi-layer graphene

When quantum flavor Hall insulator phases of itinerant fermions are disordered by strong quantum fluctuations, the condensation of skyrmion textures of order parameter fields can lead to superconductivity. In this work, we address the mechanism of skyrmion condensation by considering the scattering between (2+1)-dimensional, Weyl fermions and hedgehog-type tunneling configurations of order parameters that violate the skyrmion-number conservation law. We show the quantized, flavor Hall conductivity controls the degeneracy of topologically protected, fermion zero-modes, localized on hedgehogs. The overlap between zero-mode eigenfunctions or 't Hooft vertex is shown to control the nature of paired states. Employing this formalism for the N=2 model of twisted bilayer graphene, we describe the competition among flavor Hall orders, charge 4e superconductors, and various charge 2e paired states in BCS and pair-density-wave channels. For the charge neutral system, the competition between flavor Hall insulators and charge 2e states can be captured by SO(9) non-linear sigma models.

Peizhi Mai
University of Illinois Urbana-Champaign

Compressibility and topology in the Haldane-Hofstadter-Hubbard model

The recent observation of Hofstadter spectrum in Magic-angle twisted bilayer graphene renews interest in studying the behavior of strongly correlated electronic systems in strong magnetic fields. We simulate the Haldane-Hofstadter-Hubbard model in honeycomb lattice with determinant quantum Monte-Carlo methods. We calculate the compressibility and topological properties for this system as a function of interaction strength and magnetic flux. We find the general structure of Hofstadter spectrum is preserved in the presence of small to intermediate interaction strength. We also find that the topological quantities like berry curvature preserved for interaction U no larger than 4t.

*Work done in collaboration with Edwin W. Huang and Philip W. Phillips.

Sanu Mishra* - cancelled
Los Alamos National Laboratory

Critical currents across grain boundaries in polycrystalline $CeCoIn_5$

The study of grain boundaries (GB) in superconductors has both fundamental and applied interests. In high temperature cuprate superconductors studies of the critical currents (J_c) across GBs have provided important information on the symmetry of the order parameter and are critical for the observation of spontaneously generated half-flux magnetic quanta [1]. Similar to cuprate superconductors, heavy fermion superconductors (HFS) host rich physics in the form of unconventional superconducting phases with nodal quasiparticles. However, there have been relatively few phase sensitive measurements of the order parameter thereby emphasizing the need for investigations of J_c across GBs in HFS.
In this poster, I will present results on GBs in polycrystalline samples of the HFS $CeCoIn_5$. Electron backscatter diffraction images of well-polished samples reveal that majority of grains are not randomly oriented as one would expect but grow at an angle of 90° with respect to their neighboring grain. We are performing J_c studies on various such GBs. Such investigations are crucial to understand the superconducting order parameter symmetry of $CeCoIn_5$ and its potential use in devices for quantum information science.

1. H. Hilgenkamp et al., Rev. Mod. Phys. 74, 485, 2002

*Work done in collaboration with S. M. Thomas, R. McCabe, S-Z Lin, E. D. Bauer, F. Ronning

Alexander Tyner
Northwestern University

Symmetry indicators vs. bulk winding numbers of topologically non-trivial bands

The symmetry-indicators provide valuable information about the topological properties of band structures in real materials. For inversion-symmetric, non-magnetic materials, the pattern of parity eigenvalues of various Kramers-degenerate bands at the time-reversal-invariant momentum points are generally analyzed with the combination of strong $Z4$, and weak $Z2$ indices. Can the symmetry indicators identify the tunneling configurations of SU(2) Berry connections or the three-dimensional, winding numbers of topologically non-trivial bands? If the parity eigenvalues are regarded as fictitious Ising spins, located at the vertices of Miller hypercube, the strong $Z4$ index describes the net ferro-magnetic moment, which is shown to be inadequate for identifying non-trivial bands, supporting even integer winding numbers. We demonstrate that an anti-ferromagnetic index, measuring the staggered magnetization can distinguish between bands possessing zero, odd, and even integer winding numbers. By simultaneously computing ferromagnetic and anti-ferromagnetic indices, we categorize various bands of bismuth, antimony, rhombohedral phosphorus, and Bi_2Se_3.

Ashley Weiland - cancelled
Los Alamos National Laboratory, Los Alamos

A crystallographic study of UTe_2

The spin-triplet candidate superconductor UTe_2 [1] crystallizes in the Immm space group (no. 71), a = ~4.16 Å, b = ~6.14 Å, and c = ~13.98 Å, and contains three crystallographic sites, one U site which occupies the 4i position and two Te sites, where Te1 occupies the 4j position and Te2 occupies the 4h position [2]. An intrinsic multicomponent superconducting order parameter has been suggested to exist in UTe_2 [3] although contrasting reports indicate that the dual transitions arise due to inhomogeneity within the crystal [4]. This talk will focus on detailed single crystal X-ray diffraction studies to probe crystallographic differences in samples with double or single superconducting transitions to elucidate their origin.

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Andrew J. Woods*
Los Alamos National Laboratory, LANL MPA-Q

Low Temperature Heat Capacity Measurements of $KYbSe_2$

Quantum spin liquids (QSLs) are a proposed state of matter characterized by fractionalized quasiparticle excitations, quantum entanglement and a lack of long range magnetic order. QSLs have so far evaded definitive experimental observation. There has been significant study of Yb^{3+} based materials as QSL candidates due to the Yb^{3+} S = ½ state, but thus far these studies have not provided an unambiguous proof of a QSL. Here we investigate the Yb^{3+} delafossite material $KYbSe_2$, which is a promising QSL candidate.

We present low temperature ($T \geq 30$ mK) measurements of the heat capacity of single crystal $KYbSe_2$, in which we observe signatures of a magnetic ordering transition at 300 mK, consistent with neutron scattering studies of $KYbSe_2$. We discuss the effect of applying an in-plane (H‖ab) magnetic field on the transition and on the temperature dependence of the heat capacity. We use the nuclear Schottky anomaly due to static Yb electron spins to track the evolution of the magnetically ordered state as a function of magnetic field.

*Work done in collaboration with S. Lee[1], A. O. Scheie[2], C. D. Batista[2], D.A. Tennant[2], R. Movshovich[1].
[1]LANL MPA-Q
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