浙江大学 关联物质研究中心
CENTER FOR CORRELATED MATTER, ZHEJIANG UNIVERSITY

ZWCM 2024

2024年浙江关联物质国际研讨会

2024 ZHEJIANG WORKSHOP ON CORRELATED MATTER

会议手册

PROGRAM

主办单位

Organized by

浙江大学关联物质研究中心
Center for Correlated Matter, Zhejiang University

浙江大学物理学院
School of Physics, Zhejiang University

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May 8-12 , 2024 | Hangzhou, China

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2024 Zhejiang Workshop on Correlated Matter

Scope

The 2024 Zhejiang Workshop on Correlated Matter (ZWCM 2024) belongs to the Zhejiang Workshop on Correlated Matter series. The workshop is organized by the Center for Correlated Matter at Zhejiang University. We successfully organized ZWCM 2017 and ZWCM 2019, which were each attended by over 150 scholars and students from home and abroad. We are very much looking forward to seeing you in Hangzhou, one of the most scenic cities in China.

Topics

- Unconventional superconductivity
- Quantum phase transitions
- Quantum magnetism
- Correlated topological materials
- Kondo Lattice compounds

Local Committee

Co-chairs: Huiqiu Yuan, Frank Steglich

Committee Members

Ming Shi, Xin Lu, Yang Liu, Chao Cao, Michael Smidman, Yu Song, Lin Jiao, Zhentao Wang, Yuanfeng Xu

Venue

Lecture Hall at the Main Library, Zijingang Campus, Zhejiang University

（浙江大学紫金港校区图书馆主馆报告厅）

Workshop Secretary

Ying Li Email: yuanlab@zju.edu.cn

Han Chen Email: chenhan722@hotmail.com

Website

https://www.zwcm2024.com/

Scientific Program

Time	May 8	May 9	May 10	May 11	May 12
08:00-08:30		Opening speech & group photo Jiangfeng Du Frank Steglich			
		Topological states Chair: Haiqing Lin	**SC and topology** Chair: Ming Shi	**Nickelate SC I** Chair: Guanghan Cao	**High Tc cuprates** Chair: P. C. Dai
08:30-08:55		Xincheng Xie	Hong Ding	Danfeng Li	Nanlin Wang
08:55-09:20		Kai Chang	Yanwu Xie	Elbert Chia	Yayu Wang
09:20-09:45	**Tutorial lecture 1** **Piers Coleman (9:30-11:30)**	Yulin Chen	Xi Dai	Meng Wang	Xingjiang Zhou
09:45-10:10		Yuanfeng Xu	Jiangping Hu	Lin Jiao	Kui Jin
10:10-10:35		**Coffee Break**			
		Quantum magnetism I Chair: D. L. Feng	**SCES theory** Chair: P. Coleman	**Nickelate SC II** Chair: G. M. Zhang	**Low-dimensional SC** Chair: N. L. Wang
10:35-11:00		Pengcheng Dai	Tao Xiang	Haihu Wen	Xianhui Chen
11:00-11:25		Tsutomu Momoi	Guangming Zhang	Fuchun Zhang	Donglai Feng
11:25-11:50		Zhentao Wang	Zhongyi Lu	Congjun Wu	poster prize + Concluding remarks
12:00-14:00	**Lunch**				
	Tutorial lecture 2 **Ernst Bauer (1:30-3:30)** **Registration**	**Heavy fermion SC** Chair: E. Bauer	**Poster Session**	**Quantum criticality** Chair: D. Aoki	
14:00-14:25		Dai Aoki	Poster	Piers Coleman	
14:25-14:50		Seunghyun Khim		Meigan Aronson	
14:50-15:15		Yang Liu		Zhe Wang	
15:15-15:40		Akito Sakai		Oliver Stockert	
15:40-16:05		**Coffee break**			
	Tutorial lecture 3 **Pengcheng Dai (3:45-5:45)**	**Kagome lattices** Chair: Xiaoqun Wang	**Quantum magnetism II** Chair: M. Aronson	**Symposium on Strange metals** Chair: F. Steglich	
16:05-16:30		Ziqiang Wang	Steffen Wirth	P. Coleman (overview) K. Jin (Cu- & Fe- SC) M. Smidman (HF) D. F. Li (Nickelates) X. Dai (MATBG) Discussion	
16:30-16:55		Jianxin Li	Ernst Bauer		
16:55-17:20		Zurab Guguchia	Peijie Sun		
17:20-17:45		Jinsheng Wen	Lei Shu		
18:00	**Reception**	**Dinner**	**Banquet**	**Dinner**	

2024 Zhejiang Workshop on Correlated Matter

Date	Time	Program
05/08	**Tutorial lectures** (Venue: Room 215, Hainayuan Building No.8 海纳苑 8 幢 215 报告厅)	
	Tutorial lecture 1	
	09:30-11:30	Piers Coleman: *Heavy Fermion Perspectives on Quantum Materials*
	Tutorial lecture 2	
	13:30-15:30	Ernst Bauer: *Thermoelectricity beyond Bi_2Te_3*
	Tutorial lecture 3	
	15:45-17:45	Pengcheng Dai: *Using Neutron as a Probe to Study Strongly Correlated Electron Materials*
	13:00-18:00	**Registration** (Venue: Ouyamei International Hotel 欧亚美国际大酒店)
	18:00-20:00	**Reception @ 1F, Ouyamei International Hotel**
	05/09 – 05/12	**Conference Venue: Lecture Hall at the Main Library**（图书馆主馆报告厅）
05/09	**Opening Speech (Chair: Huiqiu Yuan)**	
	08:00-08:05	Jiangfeng Du (President of Zhejiang University)
	08:05-08:10	Frank Steglich (Director of the Center for Correlated Matter)
	08:10-08:30	Group photo
	Topological states (Chair: Haiqing Lin)	
	08:30-08:55	Xincheng Xie (Fudan University/Peking University, China) *Towards dissipationless topotronics*
	08:55-09:20	Kai Chang (Zhejiang University, China) *Topological exciton phase*
	09:20-09:45	Yulin Chen (University of Oxford, UK) *Strong Inter-valley Electron-Phonon Coupling in Magic-Angle Twisted Bilayer Graphene*
	09:45-10:10	Yuanfeng Xu (Zhejiang University, China) *Topological Flat-Band Materials: Classifications and Applications*
	10:10-10:35	Coffee break

Date	Time	Program

Quantum magnetism I (Chair: Donglai Feng)

10:35-11:00 Pengcheng Dai (Rice University, USA)

Emergent photons and fractionalized excitations in a quantum spin liquid

11:00-11:25 Tsutomu Momoi (RIKEN, Japan)

Dynamics of quantum spin-nematics

11:25-11:50 Zhentao Wang (Zhejiang University, China)

Direct observation of a 2-magnon bound state condensation

12:00-14:00 Lunch @ 1F, Ouyamei International Hotel

Heavy fermion SC (Chair: Ernst Bauer)

14:00-14:25 Dai Aoki (Tohoku University, Japan)

Multiple superconducting phases and Fermi surfaces in spin-triplet superconductor UTe_2

14:25-14:50 Seunghyun Khim (MPI-CPfS, Germany)

Magnetic and superconducting properties of the heavy-fermion $CeRh_2As_2$ revealed by μSR studies

14:50-15:15 Yang Liu (Zhejiang University, China)

ARPES study of Ce-based heavy fermion superconductors and thin films

15:15-15:40 Akito Sakai (The University of Tokyo, Japan)

Possible ferro-octupole order in the quadrupole Kondo lattice PrV_2Al_{20} studied by magnetostriction and thermal expansion

15:40-16:05 Coffee break

Kagome lattices (Chair: Xiaoqun Wang)

16:05-16:30 Ziqiang Wang (Boston College, USA)

Loop current and Loop supercurrent in kagome metals and superconductors

16:30-16:55 Jianxin Li (Nanjing University, China)

Fractional Magnetization Plateau and Spinon quantum Hall state in Kagome Antiferromagnets

16:55-17:20 Zurab Guguchia (Paul Scherrer Institute, Switzerland)

Date	Time	Program
		Time-Reversal Symmetry-Breaking in Charge-Ordered Kagome-Lattice Systems Probed with Muon Spin Rotation
	17:20-17:45	Jinsheng Wen (Nanjing University, China)
		Neutron Scattering Investigations of Kitaev Quantum Magnets
	18:00	Dinner @ 3F, Yinquan Cafeteria (银泉餐厅 3 楼，食天一隅)
05/10	**SC and topology (Chair: Ming Shi)**	
	08:30-08:55	Hong Ding (Tsung-Dao Lee Institute of Shanghai Jiao Tong University, China)
		Recent progress in Iron-Majorana platform
	08:55-09:20	Yanwu Xie (Zhejiang University, China)
		Superconducting quantum oscillations and anomalous negative magnetoresistance in nanohoneycomb patterned oxide interface
	09:20-09:45	Xi Dai (The Hong Kong University of Science and Technology, China)
		Heavy fermion representation for twisted bilayer graphene systems
	09:45-10:10	Jiangping Hu (Institute of Physics, CAS, China)
		Loop Current States in Correlated Electron Systems
	10:10-10:35	Coffee break
	SCES theory (Chair: Piers Coleman)	
	10:35-11:00	Tao Xiang (Institute of Physics, CAS, China)
		Spin excitation spectra of triangular Heisenberg antiferromagnets
	11:00-11:25	Guangming Zhang (Tsinghua University, China)
		Fully frustrated XY spin model on a Kagome lattice with a 1/3 fractional vortex-antivortex pairing phase transition
	11:25-11:50	Zhongyi Lu (Renmin University of China)
		Natural Orbitals Renormalization Group
	12:00-14:00	Lunch @ 1F, Ouyamei International Hotel
	14:00-15:40	**Poster Session**
	15:40-16:05	Coffee break

Date	Time	Program
	Quantum magnetism II (Chair: Meigan Aronson)	
	16:05-16:30	Steffen Wirth (MPI-CPfS, Germany) *Polaron formation in Eu-based compounds*
	16:30-16:55	Ernst Bauer (Vienna University of Technology, Austria) *Complex magnetic order in novel heavy fermion compound $YbPt_5B_2$: elastic and inelastic neutron scattering studies*
	16:55-17:20	Peijie Sun (Institute of Physics, CAS, China) *Spin Supersolid and Giant Cooling Effect in $Na_2BaCo(PO_4)_2$*
	17:20-17:45	Lei Shu (Fudan University, China) *Fluctuating magnetic droplets immersed in a sea of quantum spin liquid*
	18:30-20:30	Banquet @ Jiaolu Tianzhuang (西溪湿地，茭芦田庄)
05/11	**Nickelate SC I (Chair: Guanghan Cao)**	
	08:30-08:55	Danfeng Li (City University of Hong Kong) *Superconductivity in Thin-film Infinite-layer Nickelates*
	08:55-09:20	Elbert Chia (Nanyang Technological University, Singapore) *Elucidating the pairing symmetry of infinite-layered nikelate superconductors*
	09:20-09:45	Meng Wang (Sun Yat-sen University, China) *Experimental investigations on the nickelate high-Tc superconductors*
	09:45-10:10	Lin Jiao (Zhejiang University, China) *High-Tc superconductivity with zero resistance and strange metal behavior in $La_3Ni_2O_7$*
	10:10-10:35	Coffee break
	Nickelate SC II (Chair: Guangming Zhang)	
	10:35-11:00	Haihu Wen (Nanjing University, China) *On the way of exploration on superconductivity in nickelates*
	11:00-11:25	Fuchun Zhang (Kavli Institute, CAS, China) *Theory for high temperature superconductivity in $La_3Ni_2O_7$*

Date	Time	Program
	11:25-11:50	Congjun Wu (Westlake University, China) *Hund's assisted high Tc superconductivity in $La_3Ni_2O_7$*
	12:00-14:00	Lunch @ 1F, Ouyamei International Hotel
	Quantum criticality (Chair: Dai Aoki)	
	14:00-14:25	Piers Coleman (Rutgers University, USA) *Beyond BCS: Possible Implications of Spin Fractionalization for Novel Superconductivity*
	14:25-14:50	Meigan Aronson (University of British Columbia, Canada) *One-Dimensional Quantum Criticality in the Metallic Spin Chain Ti_4MnBi_2*
	14:50-15:15	Zhe Wang (Technical University of Dortmund, Germany) *Many-body magnon bound states in a transverse-field Ising-chain antiferromagnet*
	15:15-15:40	Oliver Stockert (MPI-CPfS, Germany) *Phonon softening at the structural instability in $Lu(Pt_{1-x}Pd_x)_2In$*
	15:40-16:05	Coffee break
	Symposium on Strange metals (Chair: Frank Steglich)	
	16:05-16:20	Piers Coleman (Rutgers University, USA) *overview*
	16:20-16:35	Kui Jin (Institute of Physics, CAS, China) *Cu- and Fe- superconductivity*
	16:35-16:50	Michael Smidman (Zhejiang University, China) *Heavy fermions*
	16:50-17:05	Danfeng Li (City University of Hong Kong) *Nickelate superconductors*
	17:05-17:20	Xi Dai (The Hong Kong University of Science and Technology, China) *MATBG*
	17:20-17:45	Discussion
	18:00	Dinner @ 3F, Yinquan Cafeteria (银泉餐厅 3 楼，食天一隅)

Date	Time	Program
05/12		**High Tc cuprates (Chair: Pengcheng Dai)**
	08:30-08:55	Nanlin Wang (Peking University, China)
		Detecting Higgs mode and its coupling with other collective modes developed in the pseudogap phase in cuprate superconductor
	08:55-09:20	Yayu Wang (Tsinghua University, China)
		Visualizing the atomic and molecular orbital basis for pair formation in cuprate
	09:20-09:45	Xingjiang Zhou (Institute of Physics, CAS, China)
		Laser ARPES on Pairing Symmetry and Electronic Origin of High-Tc in High Temperature Superconductors
	09:45-10:10	Kui Jin (Institute of Physics, CAS, China)
		Scaling relations to link the strange metal state and superconductivity in overdoped cuprates
	10:10-10:35	Coffee break
	Low-dimensional SC (Chair: Nanlin Wang)	
	10:35-11:00	Xianhui Chen (University of Science and Technology of China)
		Spin-orbit coupling and superconducting stripes in an oxide heterostructure EuO/KTO(110)
	11:00-11:25	Donglai Feng (University of Science and Technology of China)
		Electronic and magnetic excitations of (La, Ca)NiO_2 and La_3Ni2O_7
	Closing Session (Chair: Huiqiu Yuan)	
	11:25-11:50	1. Announce the Best Poster Prize
		2. Concluding remarks
	12:00-14:00	Lunch @ 1F, Ouyamei International Hotel

Attendee Information

Contact Information

Huiqiu Yuan (Prof.) Mobile: 15925666127 Email: hqyuan@zju.edu.cn

Ying Li (Secretary) Mobile: 13958119681 Email: yuanlab@zju.edu.cn

Hotel Information

1）**Ouyamei International Hotel（欧亚美国际大酒店）**

Adress: No. 859 Shixiangxi Road, Xihu District, Hangzhou, China

(地址：中国浙江省杭州西湖区石祥西路859号（紫金创业园）1号楼)

Tel.: +86-571-81959999

2）**Qizhen Hotel（圆正·启真酒店）**

Add: 866 Yuhangtang Road, Hangzhou (Inside Zijingang Campus, Zhejiang University)

(地址：杭州市余杭塘路866号浙大紫金港校区内)

Tel.: +86-571-88982888

3）**Zijingang International Hotel（杭州紫金港国际饭店 ）**

Add: 707 gudun road, xihu district,hangzhou city, zhejiang province, china

（地址：中国浙江省杭州市西湖区796号）

Tel: +86-571-89710000

Wifi Connection (Lecture Hall at the Main Library)

Step 1: Connect to the wifi **ZJUWLAN**.

Step 2: Use your web browser to open any web page, and then type in the account **hwzx** and password **zju_0509.**

Currency and Banking

The Chinese currency is RMB.

Chinese banks are typically open at 9:00 and close at 16:30 from Monday to Saturday. ATMs from several major Chinese banks are available in or near the campus. Visa, Master and other major debit/credit cards may be used. However, we recommend you to exchange the currency at the airport. Note that only cash (RMB) is accepted by taxi drivers and some restaurants.

Electricity

The standard voltage in China is 220V, 50 HZ, AC.

The outlet is three-pronged and you are recommended to bring your own adaptor.

For a list of the outlets and plugs used in China, you may check：

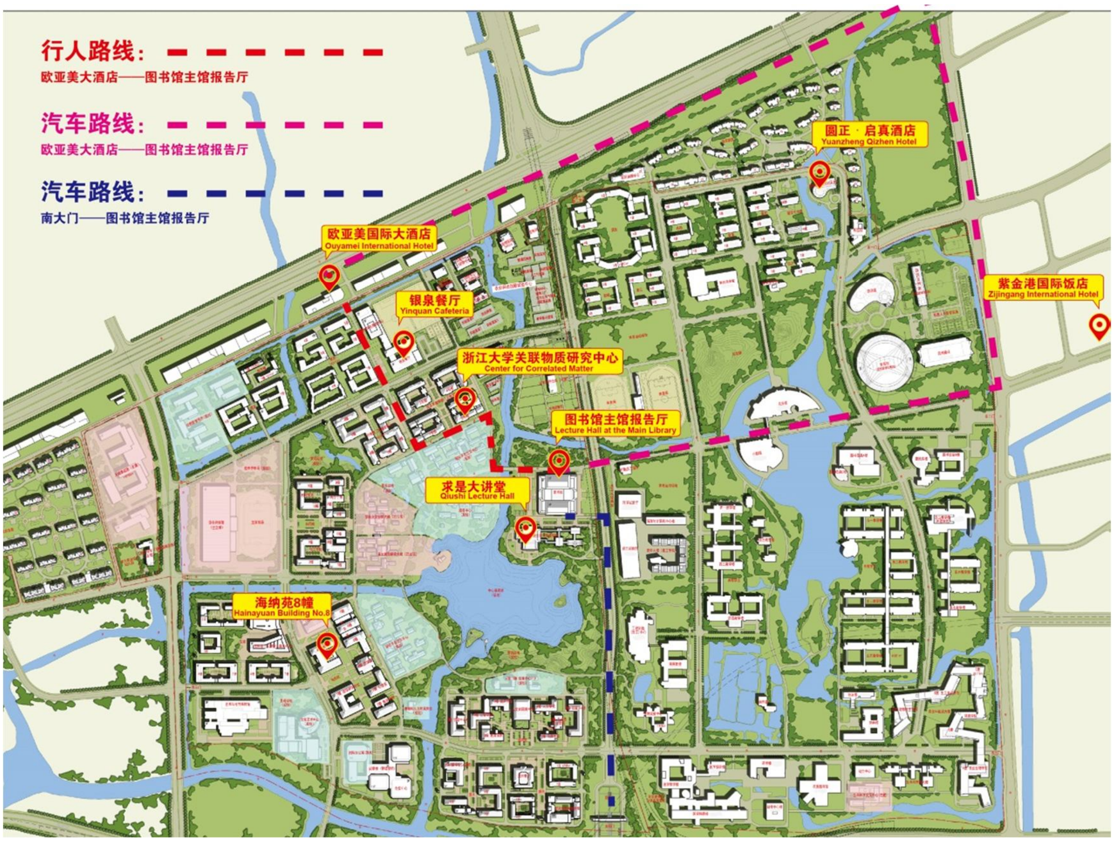
http://electricaloutlet.org/

Weather

Late September is a comfortable season in Hangzhou. The average temperature typically ranges from 20℃ to 30℃.

Maps

Please find both the maps of the campus and the conference venue.



Conference venue:

Lecture Hall at the Main Library, Zijingang Campus

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Abstracts of Talks

Towards dissipationless topotronics

Xincheng Xie

Fudan University / Peking University, China

Electrical charge transport in traditional nanoscale integrated circuits is always accompanied by energy dissipation in the form of Joule heating, which imposes a thermal bottleneck constraining their performance. The emergence of novel topological systems opens up exciting avenues for optimizing thermal management based on the intuitive concept of "no backscattering, no dissipation". However, whether energy dissipation can emerge without backscattering inside topological systems remains a question. In this work, we propose a microscopic picture that illustrates energy dissipation in the quantum Hall plateau regime of graphene. Despite the quantization of Hall, longitudinal, and two-probe resistances, we find that the energy dissipation emerges in the form of Joule heat.

In practice, such energy dissipation phenomenon is universal in topological devices, which casts doubt upon whether it is possible to reach truly dissipationless in topotronics. We propose a criterion for judging whether energy dissipation occurs inside a topological device. This criterion establishes a concise algebraic relationship among the number of modes engaged in transport, $N_{in}= N_{tunl}+ N_{bs}$. We advocate for the indispensability of Chern insulators with higher Chern numbers to achieve functional devices and uphold the no dissipation rule simultaneously. Our work holds promise for shaping the future of integrated topological circuit designs towards no dissipation.

Strong Inter-valley Electron-Phonon Coupling in Magic-Angle Twisted Bilayer Graphene

Yulin Chen

University of Oxford, UK

The unusual properties of superconductivity in magic-angle twisted bilayer graphene (MATBG) have sparked enormous research interest. However, despite the dedication of intensive experimental efforts and the proposal of several possible pairing mechanisms, the origin of its superconductivity remains elusive. Here, using angle-resolved photoemission spectroscopy with micrometer spatial resolution, we discover replicas of the flat bands in superconducting MATBG unaligned with its hexagonal boron nitride (hBN) substrate, which are absent in non-superconducting MATBG aligned with the hBN substrate. Crucially, the replicas are evenly spaced in energy, separated by 150 ± 15 meV, signalling the strong coupling of electrons in MATBG to a bosonic mode of this energy. By comparing our observations to simulations, the formation of replicas is attributed to the presence of strong inter-valley electron-phonon coupling to a K-point phonon mode. In total, the observation of these replica flat bands and the corresponding phonon mode in MATBG could provide important information for understanding the origin and the unusual properties of its superconducting phase.

Topological Flat-Band Materials: Classifications and Applications

Yuanfeng Xu

Center for correlated matter and school of physics, Zhejiang University

Flat bands in crystalline materials come in two kinds: atomically flat and topologically flat. Flat atomic bands are topologically trivial and commonly exist in layered materials and heavy fermion systems. Topological flat bands were recently discovered in twisted 2D materials, where the coexistence of nontrivial band topology and strong electronic correlation manifests kinds of exotic quantum phases, such as quantum anomalous Hall effect, magnetism, correlated insulating states, and superconductivity, etc. In addition, a few 2D line-graph lattices with s orbitals were also proposed to have topological flat bands in the tight-binding approximation. Compared with the twisted superlattice, stoichiometric flat-band materials are much easier to synthesize and have a larger carrier density. I'll introduce a general construction of flat bands in both 2D and 3D crystals. Using the magnetic topological quantum chemistry theory, we have a full classification of topological flat bands in paramagnetic and magnetic materials both with and without spin-orbit coupling. These advantages enable a complete understanding of flatten band features in most materials. By analyzing the geometry and symmetry properties, a high-throughput search and classification of topological flat-band materials were performed to build a materials database. We further investigate a set of compounds and show that their band flatness are the result of more convoluted properties than simple Kagome flat bands.

Emergent photons and fractionalized excitations in a quantum spin liquid

Pengcheng Dai

Department of Physics and Astronomy, Rice University, Houston, Texas 77005, USA

A quantum spin liquid (QSL) arises from a highly entangled superposition of many degenerate classical ground states in a frustrated magnet, and is characterized by emergent gauge fields and deconfined fractionalized excitations (spinons). Because such a novel phase of matter is relevant to high-transition-temperature superconductivity and quantum computation, the microscopic understanding of QSL states is a long-sought goal in condensed matter physics. Although Kitaev QSL exists in an exactly solvable spin-1/2 (S=1/2) model on a two-dimensional (2D) honeycomb lattice, there is currently no conclusive identification of a Kitaev QSL material. The 3D pyrochlore lattice of corner-sharing tetrahedra, on the other hand, can host a QSL with U(1) gauge fields called quantum spin ice (QSI), which is a quantum (with effective S=1/2) analog of the classical (with large effective moment) spin ice. The key difference between a QSI and classical spin ice is the predicted presence of the linearly dispersing collective excitations near zero energy, dubbed the "photons" arising from emergent quantum electrodynamics, in addition to the spinons at higher energies. Recently, 3D pyrochlore systems $Ce_2M_2O_7$ (M = Sn, Zr, Hf) have been suggested as effective S=1/2 QSI candidates, but there has been no evidence of quasielastic magnetic scattering signals from photons, a key signature for a QSI. Here, we use polarized neutron scattering experiments on single crystals of $Ce_2Zr_2O_7$ to conclusively demonstrate the presence of magnetic excitations near zero energy at 50 mK in addition to the signatures of spinons at higher energies. By comparing the energy (E), wave vector (Q), and polarization dependence of the magnetic excitations with theoretical calculations, we conclude that $Ce_2Zr_2O_7$ is the first example of a dipolar-octupolar π-flux QSI with dominant dipolar Ising interactions, therefore identifying a microscopic Hamiltonian responsible for a QSL.

Dynamics of quantum spin-nematics

Tsutomu Momoi

RIKEN, Japan

A spin-nematic order in spin systems is characterized by the absence of a magnetic Bragg peak and a broken partial spin rotation symmetry due to spin quadrupolar order. Identifying spin-nematic states in experiments is challenging due to the absence of Bragg peaks.
Dynamical quantities show promise as valuable tools for identifying spin-nematic states. For instance, in one-dimensional spin-nematic Tomonaga-Luttinger liquids, the temperature dependence of the NMR relaxation rate exhibits a slower decay compared to conventional one-dimensional antiferromagnets, enabling the detection of spin-nematic liquids [1]. However, a comprehensive understanding of dynamical properties in three-dimensional spin-nematic ordered phases is yet to be established.

Here, we investigated the dynamical properties of spin-nematic states in three-dimensional quantum spin systems in a magnetic field [2]. We used a two-component boson theory incorporating magnons and bimagnons to investigate the dynamical spin structure factor at zero temperature and the nuclear magnetic resonance (NMR) relaxation rate at finite temperatures. Our findings revealed that the dynamical structure factor does not exhibit any diverging singularity across momentum and frequency while providing valuable information about the form factor of bimagnon states and the underlying structure of spin-nematic order. Furthermore, we find a temperature dependence in the NMR relaxation rate proportional to T^3 at low temperatures, similar to canted antiferromagnets. A clear distinction arises as there is no critical divergence of the NMR relaxation rate at the spin-nematic transition temperature. Our theoretical framework provides a comprehensive understanding of the excitation spectrum and the dynamical properties of spin-nematic states, covering arbitrary spin values S and encompassing site and bond nematic orders.

[1] M. Sato, T. Momoi, and A. Furusaki, Phys. Rev. B 79, 060406(R) (2009).
[2] T. Momoi, Phys. Rev. Research 6, 013169 (2024).

E Direct observation of a 2-magnon bound state condensation

Zhentao Wang

Center for correlated matter and school of physics, Zhejiang University

In ordered magnets, the elementary excitations are typically the spin waves (magnons), which obey Bose-Einstein statistics. Similarly to the Cooper pairs in superconductors, the magnons can be paired into bound states under attractive interactions. Even more interestingly, the magnetic field acts as a chemical potential term that is able to tune such boson pair through a quantum critical point, beyond which a ``hidden order'' was predicted to exist. In this talk, we demonstrate that this exotic phenomenon is finally directly observed in a triangular lattice spin-1 magnet.

Multiple superconducting phases and Fermi surfaces in spin-triplet superconductor UTe2

Dai Aoki

IMR, Tohoku University, Japan

Unconventional superconductivity of the heavy fermion paramagnet UTe2 is one of the hottest topics in the strongly correlated electron systems. Superconductivity occurs below Tc=1.5-2K with the large specific heat jump, indicating the strong coupling regime. The huge and anisotropic upper critical field Hc2 resembles those observed in the ferromagnetic superconductors URhGe and UCoGe. However, the ferromagnetic fluctuations in UTe2 are not experimentally established, instead the antiferromagnetic fluctuations with the incommensurate q-vector is directly observed in the inelastic neutron scattering experiments. One of the highlights of UTe2 is the field-reentrant superconductivity, which appears up to Hm=35T, when the field is applied along the hard magnetization b-axis in the orthorhombic structure. Another remarkable point is the multiple superconducting phases under pressure, indicating the different superconducting order parameters. These significant properties are consistent with the spin-triplet state, which has the spin and orbital degree of freedom. A key experimental target is to determine the Fermi surface properties by means of the quantum oscillations experiments using high quality single crystals. In this talk, we review our recent results on UTe2. The focus is given on Fermi surfaces, multiple superconducting phases, and field-induced superconductivity.

Magnetic and superconducting properties of the heavy-fermion $CeRh_2As_2$ revealed by μSR studies

Seunghyun Khim, Oliver Stockert, Manuel Brando, and Christoph Geibel

Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Straße 40, 01187 Dresden,Germany

Chirstopher Baines, Thomas J. Hicken, Hubertus Leutkens,

Debarchan Das, Toni Shiroka, Zurab Guguchia, and Robert Scheuermann

Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland

The superconducting state (T_c = 0.3 K) of the heavy-fermion compound $CeRh_2As_2$, which demonstrates an unusual field-induced transition to another high-field SC state, emerges from an unknown ordered state below T_o = 0.55 K. While an electronic multipolar order of itinerant Ce-4f moments was proposed to account for the T_o phase, the exact order parameter has not been known to date. Here, we report on muon spin relaxation (μSR) studies of the magnetic and superconducting properties in $CeRh_2As_2$. We reveal a magnetic origin of the T_o order by identifying a spontaneous internal field. Furthermore, we find evidence of a microscopic coexistence of local magnetism with bulk superconductivity. Our findings open the possibility that the T_o phase involves both dipole and higher-order Ce-4f moment degrees of freedom and accounts for the unusual non-Fermi liquid behavior.

ARPES study of Ce-based heavy fermion superconductors and thin films

Yang Liu

Center for Correlated Matter and School of Physics, Zhejiang University

The dual nature of 4f electrons (localized or itinerant) plays a key role in the rich physics of Ce-based heavy fermion systems, leading to diverse ground states, including heavy fermion superconductivity, strange metal, orbital order, etc. Revealing the Fermi surface (FS), particularly FS sheets with large effective masses, is important for understanding the strong electron correlation and the underlying mechanism of these phases. In this talk, we will report our recent ARPES studies of two Ce-based heavy fermion superconductors, namely $CeCu_2Si_2$ [1] and $CeRh_2As_2$ [2]. We will show how the quasiparticle dispersion and FS obtained from ARPES measurements can be helpful for understanding the unconventional superconductivity and magnetic excitations in these systems [3]. If time permits, we will also show how the combination with thin film growth by MBE allows for fine tuning of the 4f states [4,5].

Reference

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Possible ferro-octupole order in the quadrupole Kondo lattice PrV_2Al_{20} studied by magnetostriction and thermal expansion

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The quadrupole version of Kondo effect is known as "two-channel Kondo" problem, where two independent electrons with an additional internal degree of freedom (channel) are equally hybridized with the local f electron quadrupole. As a result, the ground state for the single impurity limit becomes over-screened non-Fermi liquid, which is characterized by the fractionalized residual entropy related to the Majorana zero mode [1]. Such exotic coupling may induce further interesting phenomena in real materials with lattice periodicities [2-4].

A cubic Pr-based rare-earth compound PrV_2Al_{20} is such a quadrupole Kondo lattice system where both strong c-f hybridization and quadrupole active nonmagnetic crystalline electric field ground state (cubic Γ_3) are realized. Besides, PrV_2Al_{20} exhibits anomalous metallic behavior, multiple multipole orders at T ~ 0.7 and 0.6 K, and superconductivity at $T_c \sim 0.05$ K [5, 6]. In this presentation, we will present the possible octupole ordering in PrV_2Al_{20} that was found via our recent magnetostriction and thermal expansion measurements.

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Loop current and Loop supercurrent in kagome metals and superconductors

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Central to the vanadium-based, nonmagnetic kagome metals and superconductors AV_3Sb_5 (A=K, Cs, Rb) is a cascade of correlated quantum states triggered by an unconventional charge density wave (CDW) order. We discuss recent experimental findings, focusing on evidence for time-reversal symmetry breaking in both the normal and the superconducting state. We argue that the essential phenomenology can be captured by a 3Q CDW with loop current order, realizable in models with extended Coulomb interactions on the kagome lattice. The loop-current Chern metal has a partially filled Chern band and Chern Fermi pockets carrying concentrated Berry curvature. We show how Cooper pairing over the Chern Fermi pockets produces a chiral topological superconductor with three pairing components whose relative phases are locked at 120-degrees and loop supercurrents circulating around a vortex-antivortex lattice of pair density modulations. We discuss the extraordinary properties of this superconductor in connection to experimental observations of charge-6e flux quantization and superconductivity.

Fractional Magnetization Plateau and Spinon quantum Hall state in Kagome Antiferromagnets

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Motived by recent experimental observations of the 1/9 magnetization plateaus in kagome magnets $YCu_3(OH)_{6+x}Br_{3-x}$ and $YCu_3(OD)_{6+x}Br_{3-x}$, we study the magnetic field-induced phase transitions in the nearest-neighbor antiferromagnetic Heisenberg model on the kagome lattice using the variational Monte Carlo technique, and uncover a first-order phase transition from a zero-field Dirac spin liquid to a field-induced magnetically disordered phase exhibiting the 1/9 magnetization plateau. Through a comprehensive analysis encompassing magnetization distribution, spin correlations, chiral order parameter, topological entanglement entropy, ground-state degeneracy and Chern number, we pinpoint the phase associated with this magnetization plateau as a chiral Z_3 quantum spin liquid and elucidate its diverse physical properties.

We also elaborate that the interplay between the Dzyaloshinskii-Moriya interaction and the third nearest-neighbor antiferromagnetic interaction across the diagonals of hexagons in a kagome antiferromagnet can lead to a gapped and time-reversal symmetric Z_2 quantum spin liquid. It is an analogue to quantum spin Hall effect, but with two spinon chiral edge states.

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Time-Reversal Symmetry-Breaking in Charge-Ordered Kagome-Lattice Systems Probed with Muon Spin Rotation

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Kagome lattices stand at the forefront of research due to their fascinating interplay of topology, correlations, and magnetism [1-3]. Their special geometry enables various quantum phenomena, such as frustration and correlated orders, and features an electronic structure with flat bands, van Hove singularities, and Dirac cones. This makes them a prime subject for both experimental and theoretical research, offering insights into complex physical properties and potential technological applications. In my talk, I aim to shed light on the latest experimental developments concerning superconductivity and the magnetic aspects of charge order in various kagome-lattice systems, studied from the perspective of local magnetic probe. This involves the use of muon-spin rotation (μSR) as a function of depth from the sample surface and under extreme conditions like hydrostatic pressure, uniaxial strain, ultra-low temperatures, and high magnetic fields. μSR is complemented by magnetoresistance and X-ray diffraction techniques. Key systems under discussion will include: (1) The AV_3Sb_5 (A = K, Rb, Cs) compound series with V kagome lattice, notable for displaying a range of symmetry-breaking electronic orders, such as charge order and superconductivity. Here, we have identified a depth-tunable timereversal symmetry-breaking state associated with charge order, as well as unconventional superconductivity [4-7]. (2) The bilayer kagome material ScV_6Sn_6, where hidden magnetism within the charge-ordered state was observed [8]. (3) The $LaRu_3Si_2$ system with Ru kagome layers, in which we identified two distinct types of charge order (bond order), with one manifesting above room temperature [9,10]. This finding marks the first instance of observing a charge-ordered state at or above room temperature in a correlated kagome lattice.

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Neutron Scattering Investigations of Kitaev Quantum Magnets

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The Kitaev model is an exactly solvable quantum-spin-liquid model defined on a honeycomb lattice with S = 1/2. The key element underlying this model is the bond-anisotropic Kitaev interaction. However, in a spin-only system, it is unrealistic to have such anisotropic interactions. In this talk, I will show that the Kitaev interaction can be realized in a Mott insulator α-RuCl3, which has an effective spin of 1/2 by entangling the spin and orbital degrees of freedom. I will also show that by applying an in-plane magnetic field, the zigzag magnetic order ground state in α-$RuCl_3$ can be completely suppressed, and a quantum-spin-liquid state can be achieved. More recently, we extend the Kitaev physics to higher-spin system, where we find in a honeycomb-lattice antiferromagnet $Na_3Ni_2BiO_6$ that there is a profound 1/3 magnetization plateau, which is stabilized by the Kitaev interaction. This will also be discussed in the presentation.

Superconducting quantum oscillations and anomalous negative magnetoresistance in nanohoneycomb patterned oxide interface

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The extremely low superfluid density and unprecedented tunability of oxide interface superconductor provide an ideal platform for studying fluctuations in two-dimensional superconductors. In this talk, we present our result on $LaAlO_3/KTaO_3$ devices patterned with a nanohoneycomb array of insulating islands. Little-Parks like magnetoresistance oscillations have been observed, which is dictated by the superconducting flux quantum h/2e. An anomalous negative magnetoresistance appears under a weak magnetic field, suggesting magnetic-field-enhanced superconductivity. By examining their dependences on temperature, measurement current, and electrical gating, we conclude that both phenomena are associated with superconducting order parameter: The *h/2e* oscillation provide direct evidence of Cooper pair transport; the ANMR is related to the strong superconduting fluctuations in constricted one-dimensional superconducting channels.

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Heavy fermion representation for twisted bilayer graphene systems

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We construct a heavy fermion representation for twisted bilayer graphene (TBG) systems. Two local orbitals (per spin/valley) are analytically found, which are exactly the maximal localized zero modes of the continuum Hamiltonian near the AA center. They have similar properties to the

Wannier functions in Ref. [1], but also have a clear interpretation as the generalized zeroth Landau levels (ZLL) of Dirac fermions [2]. The electronic states of TBG can be viewed as a hybridization between these ZLL orbitals and other itinerant states which we call OPWs. Using this model, some emergent phenomenon reported previously can be understood in a unified and simple picture. Our model raises the hope for possible applications of heavy fermion theories and numerical techniques in these fascinating systems.

Loop Current States in Correlated Electron Systems

Jiangping Hu

Institute of Physics, CAS, China

In this talk, I will discuss new progress in understanding electronic loop current states in correlated electron systems. A brief review of this type states will be given for cuprates and Kagome lattice superconductors. We will develop correlated electron models where the loop current states are ground states and discuss the physics behind it.

Spin Excitation Spectra of Spin-1/2 Triangular Heisenberg Antiferromagnets

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Institute of Physics, Chinese Academy of Sciences

This talk outlines our study on the dynamical excitations of the anisotropic spin-1/2 triangular Heisenberg model. We performed a detailed numerical analysis of dynamical spectra using the state-of-the-art tensor-network renormalization-group method. Our results provide the first in-depth view of spin excitation spectra in these quantum systems, aligning well with data from inelastic neutron scattering experiments for the easy-plane antiferromagnet $Ba_3CoSb_2O_9$ and the easy-axis antiferromagnet $Na_2BaCo(PO_4)_2$. Our study uncovers how the anisotropic ratio of antiferromagnetic interactions influences spin excitation spectra. Notably, we observe roton-like features in the low-energy magnon excitations in both easy-axis and easy-plane cases. Moreover, in the easy-axis case, we identify two low-energy magnon modes: a gapless Goldstone mode and a gapped mode. These findings advance our understanding of the physics in these complex systems and set the ground for future experimental verification.

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Fully frustrated XY spin model on a Kagome lattice with a 1/3 fractional vortex-antivortex pairing phase transition

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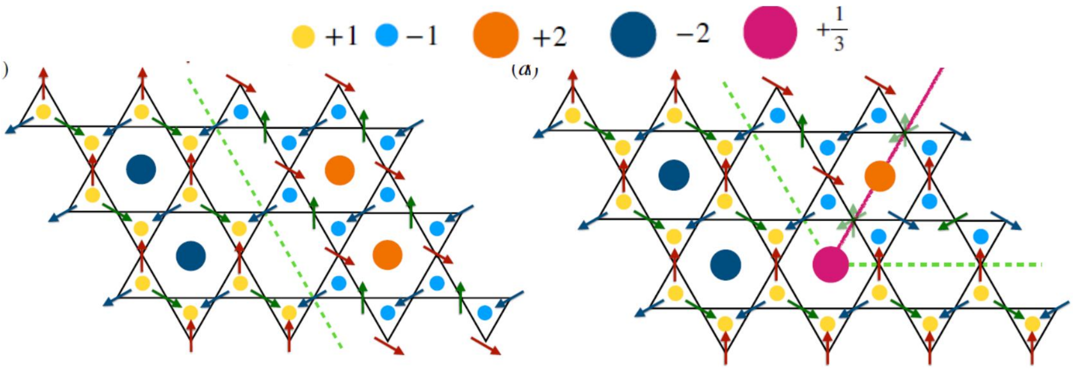
A general framework has been developed to solve the two-dimensional fully frustrated XY spin model on a Kagome lattice. The essential idea is to encode the ground-state local rules induced by frustrations in the local tensors of the partition function. Then the partition function is expressed in terms of a product of one-dimensional transfer matrix operator, whose eigen-equation can be solved by an algorithm of variational uniform matrix product states rigorously. The singularity of the entanglement entropy for the one-dimensional quantum analogue provides a stringent criterion to distinguish various phase transitions without identifying any order parameter a prior. Specially, we introduced a new representation to build the tensor network with local tensors lying on the centers of the elementary triangles of the Kagome lattice based on the duality transformation. Through a systematic numerical analysis of thermodynamic properties and correlation functions in the thermodynamic limit, we numerically proved that the model exhibits a single Berezinskii-Kosterlitz-Thouless phase transition, which is driven by the unbinding of 1/3 fractional vortex-antivortex pairs. Our result may be used to understand the charge-6e condensate observed experimentally in the vortex-antivortex lattice phase of the Kagome superconductors.



Domain wall excitations　　　　Single 1/3 fractional vortex excitation

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Natural Orbitals Renormalization Group

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The quantum renormalization group (RG) procedure is one of the most important and accurate approaches for studying interacting many-electron correlated systems, upon which we propose a new concept in the framework of natural orbitals so that we can generalize the RG into general orbital space, namely natural orbitals renormalization group (NORG). We show that for a quantum impurity model the NORG takes a polynomial (cubic power) rather than exponential computational cost in the number of electron bath sites to solve its low-energy states. Moreover, the NORG can work on a quantum impurity model with any lattice topological structure. Actually, the effectiveness of the NORG is basically irrespective of a model's topological structure. Thus, the NORG is naturally appropriate for studying quantum impurity model, especially with multi-orbital/site degrees. This makes the NORG be a natural impurity solver to dynamical mean field theory. Recently we have accomplished the DFT+DMFT software package and applied it to study correlated systems.

Polaron formation in Eu-based compounds

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Materials in which the structural, electronic and magnetic degrees of freedom are entangled can exhibit unexpected or even spectacular physical phenomena like superconductivity or colossal magnetoresistance (CMR). A hallmark of such coupled degrees of freedom is the appearance of distinct electronic phases, along with phase separation and pattern formation. One particular case of electronic inhomogeneity often observed in Eu-containing compounds are magnetic polarons, within which conduction electrons are localized via strong exchange interaction with the Eu 4*f* moments. We emphasize that Eu^{2+} is of particular interest due to its vanishing orbital angular momentum $L = 0$.

Here, we report on our investigations on three different compounds, all of which exhibit a large CMR effect. The ferromagnetic material EuB6 is presented as a benchmark case for which polaron formation is well established. We then focus on the antiferromagnetic Zintl compound $Eu_5In_2Sb_6$ which crystallizes in the non-symmorphic space group *Pbam* and hence, non-trivial topological properties can be expected. We find a record CMR and strong evidence for the occurrence of polarons in this low-carrier density material. The calculated band structures and resultant DOS for the considered antiferromagnetic and ferromagnetic spin structures in $Eu_5In_2Sb_6$ nicely illustrate how the difference in spin configuration can lead to a reorganization of the small band contributions near the Fermi level *E*F. However, at present neither our band structure calculations nor the low-temperature STS results provide any indication for a nontrivial band topology of $Eu_5In_2Sb_6$. Thermal expansion measurements indicate that $Eu_5In_2Sb_6$ is a rare example where ferromagnetic polarons coexist with an antiferromagnetic environment.

Also, $EuCd_2P_2$ exhibits an enormous CMR of up to 10^5 %. We, again, combined locally resolved investigations by Scanning Tunneling Spectroscopy with bulk measurements of the magnetic, thermodynamic and electronic transport properties and find a complex interplay of ferro- and antiferromagnetic interactions at play. The implications of inhomogeneous states in relation to possible scenarios for CMR will be discussed.

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Complex magnetic order in novel heavy fermion compound $YbPt_5B_2$: elastic and inelastic neutron scattering studies

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Novel ternary platinum borides $YbPt_5B_2$ and $LuPt_5B_2$ have been synthesized by arc melting of constituent elements and subsequent annealing at 1020 K. The unit cell of $YbPt_5B_2$ ($YbPt_5B_2$-type, monoclinic space group *C*2/*m*, *a* = 15.4982(6) Å, *b* = 5.5288(3) Å, *c* = 5.5600(3) Å, = 105.367(3) , single crystal X-ray diffraction data) is composed of two structural fragments alternating along the *a* axis and extending infinitively along the *b* axis: (i) columns of face-fused boron filled and empty edge-connected trigonal metal prisms, and (ii) zig-zag chains of B-filled trigonal prisms connected by common edges. $LuPt_5B_2$ was found to be isotypic (Rietveld refinement of powder X-ray diffraction data). $YbPt_5B_2$ exhibits two magnetic phase transitions at T_{mag1} ~ 8 K and T_{mag2} ~ 4 K as deduced from specific heat, magnetostriction, electric resistivity and magnetization data. Externally applied magnetic fields are responsible for further field induced phase transitions. The quite complex magnetic features appear to be the result of RKKY interaction and the Kondo effect in context of crystalline electric field effects [1].

In order to resolve the magnetic structure of $YbPt_5B_2$ as well as crystalline electric field features, elastic and inelastic neutron studies have been carried out on polycrystalline samples at the ISIS Facility (Rutherford Appleton Laboratory), using the high flux, high-resolution time-of-flight diffractometer WISH at temperatures down to 1 K and magnetic fields up to 8 T. INS measurements were carried out with the time-of-flight spectrometer MARI, with several incident neutron energies, from 10 K up to room temperature.

These temperature and field dependent studies essentially confirmed the previous bulk measurements, revealing antiferromagnetic T_{N1} ~ 8 K and T_{N2} ~ 4 K. While simple antiferromagnetism was obtained for $T < T_{N2}$ with a propagation vector k_{com} = (0,0,0) and Yb-magnetic-moments as large as 3.04 μ_B (T = 1.5 K), the propagation vector dramatically modifies for $T_{N2} < T < T_{N1}$, together with a change of the ordered magnetic moment, revealing an incommensurate structure k_{incom} = (0.1938, 0.0, -0.044) with a temperature dependent variation of the respective (hkl) values. Modifications of the magnetic structure and the respective magnetic moments owing the application of external fields were derived from elastic neutron studies, too.

In order to explain temperature dependent quantities, such as the specific heat, the knowledge of the crystalline electric field is indispensable. The present inelastic neutron studies allowed to derive the crystal field level scheme and associated magnetic moments. A doublet as ground state, involving all wave functions from |-7/2| to |7/2>, explains the magnetic moments at low temperature and the large splitting of the first excited level from the ground state accounts for an extended temperature range with almost constant entropy.

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Spin Supersolid and Giant Cooling Effect in $Na_2BaCo(PO_4)_2$

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A spin supersolid is a quantum magnetic state that simultaneously shows two seemingly contradictory features: spin solid order and spin superfluid order. Recently we have found evidence of spin supersolid in a triangular-lattice antiferromagnet Na2BaCo(PO4)2 through intensive thermodynamic and neutron scattering measurements, as well as quantum many body simulations. Neutron diffractions measured down to 30 mK successfully locate the proposed spin supersolid phases by revealing the coexistence of three-sublattice spin solid order and interlayer incommensurability indicative of the spin superfluidity. Notably, a giant magnetocaloric effect related to the spin supersolidity is observed in the demagnetization cooling process, manifesting itself as two prominent low-temperature valley-like regimes. These results reveal a strong entropic effect of spin supersolid state and open up a viable and promising avenue for applications in sub-kelvin refrigeration. For details, see Xiang et al., Nature 625, 270 (2024).

Fluctuating magnetic droplets immersed in a sea of quantum spin liquid

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The search of quantum spin liquid (QSL), an exotic magnetic state with strongly-fluctuating and highly-entangled spins down to zero temperature, is a main theme in current condensed matter physics. However, there is no smoking-gun evidence for deconfined spinons in any QSL candidate so far. The disorders and competing exchange interactions may prevent the formation of an ideal QSL state on frustrated spin lattices. Here we report comprehensive and systematic measurements of the magnetic susceptibility, ultralow-temperature specific heat, muon spin relaxation (μSR), nuclear magnetic resonance (NMR), and thermal conductivity for $NaYbSe_2$ single crystals, in which Yb^{3+} ions with effective spin-1/2 form a perfect triangular lattice. All these complementary techniques find no evidence of long-range magnetic order down to their respective base temperatures. Instead, specific heat, μSR and NMR measurements suggest the coexistence of quasi-static and dynamic spins in $NaYbSe_2$. The scattering from these quasi-static spins may cause the absence of magnetic thermal conductivity. Thus, we propose a scenario of fluctuating ferrimagnetic droplets immersed in a sea of QSL. This may be quite common on the way pursuing an ideal QSL, and provides a brand-new platform to study how a QSL state survives impurities and coexists with other magnetically ordered states.

Superconductivity in Thin-film Infinite-layer Nickelates

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Developing new techniques to design and discover novel superconductors, especially those with unusual symmetries of superconducting order parameters and/or exotic pairing mechanisms, opens new doors to future applications in quantum devices. The recent discovery of superconductivity in infinite-layer nickelates has engendered reviving interest in the study of a cuprate-analog system [1]. Notably, superconducting nickelates display signatures of intriguing similarities and distinctions to the cuprates in their phase diagrams, proximity to strongly correlated electronic phases [2,3], antiferromagnetic interactions [4], superconducting anisotropy [5], etc. Partially owing to the non-trivial challenges in materials synthesis and their thin-film nature, experimental demonstration of the intrinsic properties of this materials family has still been limited. In this talk, I will introduce this new family of superconductors synthesized by a soft-chemistry approach and highlight the key aspects of their electronic and magnetic structure. I will also present our latest developments in synthetic approaches to the materials system and probing of their distinct features, in a broader context of the unusual role that rare-earth elements and chemical environment play [6]. Finally, I will suggest how new applications of kinetic-based synthetic approaches in oxide heterostructures provide a broad opportunity to create novel nickelate systems in previously inaccessible ways [7].

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Elucidating the pairing symmetry of infinite-layered nikelate superconductors

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The superconducting infinite-layer nickelate family has risen as a promising platform for revealing the mechanism of high-temperature superconductivity. However, its challenging material synthesis has obscured effort in understanding the nature of its ground state and low-lying excitations, which is a prerequisite for identifying the origin of the Cooper pairing in high-temperature superconductors. In particular, the superconducting gap symmetry of nickelates has hardly been investigated and remains controversial. Here, we report the pairing symmetry of the infinite-layer nickelates determined by London penetration depth measurements in neodymium-based (Nd,Sr)NiO_2 and lanthanide-based (La,Ca)NiO_2 thin films of high crystallinity. Our microscopic analysis reveal that a complex order parameter is able to explain the temperature dependence of both samples. In contrast to the cuprates, our results suggest that the superconducting order parameter in the nickelates is beyond a single d-wave gap.

Experimental investigations on the nickelate high-T_c superconductors

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Since the discovery of superconductivity at 80 K in single crystals of $La_3Ni_2O_7$ at pressures above 14.0 GPa [1-5], extensive efforts have been made to understand the properties of the bilayer nickelate system at both ambient and high pressures. CDW, SDW, structural transition, strange metal behavior, orbital dependent correlations, etc. which are profound in copper oxide and iron-based superconductors also present in the pressure-dependent phase diagram of $La_3Ni_2O_7$. They may be related or irrelevant to the superconductivity of nickelates under pressure. Currently, many questions are open. In this talk, I will briefly introduce the discovery of the superconductivity in $La_3Ni_2O_7$ and discuss the research progress in nickelate superconductors [6-13].

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High-Tc superconductivity with zero resistance and strange metal behavior in $La_3Ni_2O_7$

Lin Jiao

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Recently signatures of superconductivity were observed close to 80 K in $La_3Ni_2O_7$ under pressure. This discovery positions $La_3Ni_2O_7$ as the first bulk nickelate with high-temperature superconductivity, but the lack of zero resistance presents a significant drawback for validating the findings. In this talk, I will report transport measurements under pressure up to 30 GPa using a liquid pressure medium. We observed clear evidence for superconductivity in single crystals of $La_3Ni_2O_7$ with zero resistance. Analysis of the normal state T-linear resistance suggests an intricate link between this strange metal behaviour and superconductivity, whereby at high pressures both the linear resistance coefficient and superconducting transition are slowly suppressed by pressure, while at intermediate pressures both the superconductivity and strange metal behaviour appear disrupted, possibly due to a nearby structural instability. These results provide a modified p-T phase diagram for $La_3Ni_2O_7$. I will also discuss the association between strange metal behaviour and high-temperature superconductivity as observed in many other unconventional superconductors.

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On the way of exploration on superconductivity in nickelates

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We will report the progress of our studies on physical properties and superconductivity in nickelate systems. We have carried out the first study on single particle tunneling of the infinite layer superconducting thin films of $Nd_{1-x}Sr_xNiO_2$. Our results uncover a dominant *d*-wave pairing[1] with the maximum gap value of about 4 meV, indicating the pairing induced by the repulsive interaction. We also conducted many experiments in synthesizing the infinite layer $RE_{1-x}Sr_xNiO_2$ bulk samples and all show the absence of superconductivity[2]. Recently, we have carried out many local studies by using high resolution TEM, and several possible reasons for the absence of superconductivity in bulk samples are addressed. We have also witnessed superconductivity in $La_3Ni_2O_7$ and $La_4Ni_3O_{10}$ samples[3] under pressure. For $La_3Ni_2O_7$ single crystals at ambient pressure, we found orbital selective strong correlation effect by far-infrared optics[4]. Preliminary STM studies on the $La_3Ni_2O_7$ single crystals unravel a gap in the scale of ±98 meV near the Fermi energy. Recent measurements on $La_3Ni_2O_7$ thin films show a temperature dependent Hall coefficient and a Kondo insulating behavior in low temperature region, indicating a dominant contribution by the Ni-$3d_{x2-y2}$ to the charge dynamics, and Hund coupling with the Ni-$3d_{z2}$ orbitals.

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Theory for high temperature superconductivity in $La_3Ni_2O_7$

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Recent discovery of high temperature superconductivity $La_3Ni_2O_7$ under high pressure has attracted a lot of attention. In this talk, I shall present our theory [1,2,3] for electronic structure of the compound and address the similarity and difference of this newly discovered bilayer nickelate superconductor in comparison with high temperature superconducting cuprates [4,5] and with infinite layer nickelate superconductors [6,7].

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Hund's assisted high Tc superconductivity in $La_3Ni_2O_7$

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The newly discovered high-temperature superconductivity in $La_3Ni_2O_7$ under pressure has attracted a great deal of attention. The essential ingredient characterizing the electronic properties is the bilayer NiO_2 planes coupled by the interlayer bonding of $3d_{z2}$ orbitals through the intermediate oxygen atoms. Based on Hund's rule coupling on each site and integrating out the $3d_{z2}$ spin degree of freedom, the system reduces to a single-orbital bilayer t−J model based on the $3d_{x2-y2}$ orbital. Near the physically relevant 1/4-filling regime (doping δ=0.3~0.5), the interlayer coupling $J_\perp$ of $3d_{x2-y2}$ orbital bands tunes the conventional single-layer d-wave superconducting state to the s-wave one. A strong $J_\perp$ enhances the interlayer superconducting order, leading to a dramatically increased Tc.

Beyond BCS: Possible Implications of Spin Fractionalization for Novel Superconductivity

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For more than sixty years, physicists have assumed that the only pathway to superconductivity in electronic systems, is through the BCS mechanism of pair condensation. The discovery of electron and spin fractionalization in quantum matter opens the possibility of new pathways to superconductivity, superconductivity in which spin-entanglement and fractionalization offers a new pathway to superconductivity. In flat band, and heavy fermion materials superconductivity is formed through the entanglement of local moments with electrons. I will discuss the role of spin fractionalization in the formation of singlet and triplet paired heavy fermion superconductors. In most heavy fermion superconductors, local moments entangle with electrons to produce heavy electrons. I will discuss how this process can give rise to superconductvitiy, including the possibility of pairing between electrons and Majorana fermions within spin-liquids, which can give rise to topological superconductivity [1,2,3]. I will illustrate these ideas by discussing the heavy fermion superconductors, CeCoIn5, NpAl_2Pd_5, UBe_13 and particulary, UTe_2.

Work supported by the US National Science Foundation grant DMR-1830707

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One-Dimensional Quantum Criticality in the Metallic Spin Chain Ti_4MnBi_2

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Ti_4MnBi_2 is a metallic compound consisting of well-separated chains of Mn-based spin S=1/2 magnetic moments, where the interplay of moment localization with the strong quantum fluctuations characteristic of one dimensional systems may potentially be investigated. In Ti_4MnBi_2 the near neighbor exchange is FM, coupling the Mn moments into dimers, while the inter-dimer exchange is AF. We present experimental and theoretical evidence that Ti_4MnBi_2 is well described by the J_1-J_2 XXZ model, and is in proximity of a novel quantum critical point (QCP) that separates two one-dimensional phases: a uniform FM phase when the FM intradimer exchange prevails, and an AF phase when the AF interdimer exchange dominates.

Broad peaks in the magnetic susceptibility and specific heat suggest magnetic correlations are extremely short-ranged in Ti_4MnBi_2, and measurements of the elastic neutron scattering find only a very weak modulation near q_L~0.6 rlu, with a breadth that limits correlations to the unit cell. This modulation is quickly suppressed with increased temperature, and the elastic scattering is transformed into quasielastic scattering whose increasing linewidths suggest the breakdown of critical dynamics associated with a QCP.
Inelastic neutron scattering measurements reveal the presence of a spinon continuum that agrees well with DMRG results carried out on the J_1-J_2 Hamiltonian with $J_2/|J_1|$=-0.7 placing Ti_4MnBi_2 on the AF side of the QCP $J_2/|J_1|$=0.25, while the corresponding exchange anisotropy ε_2=0.425 implies substantial Ising character. The spinon continuum is broad and gapless, with E/T scaling establishing that these excitations comprise a Luttinger Liquid. A weak FM magnon-like dispersion coexists with the spinons, signaling the proximity of Ti_4MnBi_2 to the J_1-J_2 QCP.

These observations indicate that the interchain coupling is extremely weak in Ti_4MnBi_2, so that it is far from long-ranged magnetic order. The competition between the FM dimers and their AF coupling results in strong frustration, resulting in its proximity to a novel QCP that is accompanied by the critical slowing down of correlations that are almost purely local. Due to the robustness of its one dimensionality and the relative strengths of the inter- and intra-dimer coupling, Ti_4MnBi_2 forms very close to a QCP that is inherently one-dimensional.

This work was carried out at the Stewart Blusson Quantum Materials Institute at the University of British Columbia in collaboration with Xiyang Li, Kateryna Foyetsova, and Alberto Nocera. We acknowledge funding from the National Science and Engineering Research Council of Canada, and as well the Canada First Research Excellence Fund support for the SBQMI. MCA and XL acknowledge support from the Division of Materials Research of the National Science Foundation.

Many-body magnon bound states in a transverse-field Ising-chain antiferromagnet

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One dimensional quantum spin models have been invented for more than a century, and a textbook example for illustrating basic physical concepts such as magnon, fractional excitation, quantum phase transition, etc. In this talk I will present our recent studies on a solid-state realization of the transverse-field Ising chain antiferromagnet by using high-resolution terahertz spectroscopy and other techniques in high magnetic fields. In particular, I will discuss on the manifestations of transverse-field Ising-chain quantum criticality and on the identification of high-energy repulsively bound magnons by comparing to analytical and numerical exact results. These results provide a new understanding of the quantum spin dynamics in the paradigmatic one-dimensional quantum magnetic system.

Phonon softening at the structural instability in $Lu(Pt_{1-x}Pd_x)_2In$

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Although magnetic quantum critical points have been studied extensively in the past, remarkably little work has been devoted to structural instabilities occurring at absolute zero temperature. The structural transition in $LuPt_2In$ attracts attention for both, theorists and experimentalists, since it can be tuned to zero temperature T = 0 upon substituting Pd for Pt in $Lu(Pt_{1-x}Pd_x)_2In$ [1,2]. Of particular interest is the appearance of a superconducting dome around the structural quantum criticality at $x_c \approx 0{:}6$ [1,2].

We combined inelastic neutron scattering and high-resolution inelastic x-ray scattering measurements and studied in detail this structural transition in single crystalline $Lu(Pt_{1-x}Pd_x)_2In$ [3]. From our experiments we revealed the low-energy phonon disper- sions and clearly identied the relevant phonon branch becoming soft at the structural transition. In general, the theoretical calculations broadly agree with the measured dis- persion. However, large tails of the superstructure intensity extending far above the structural transition clearly point to a non-mean- eld behavior, which might be related to quantum criticality and/or the superconducting dome.

Work performed in collaboration with T. Gruner, S. Lucas, C. Geibel, Z. Huesges, K. Kaneko. S. Tsutsui, K. Schmalzl, M. Koza, A. Hoser, and M. Reehuis

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Detecting Higgs mode and its coupling with other collective modes developed in the pseudogap phase in cuprate superconductor

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We present nonlinear terahertz third harmonic generation (THG) measurement on different doping YBa2Cu3O6+x thin films and electron-doped LCCO thin films. Different from conventional superconductors, the THG signal starts to appear in the normal state, which is consistent with the crossover temperature T* of pseudogap over broad doping levels. Upon lowering temperature, the THG signal shows anomaly just below Tc. Strikingly, we observe a beat pattern directly in the measured real time waveform of THG signal. We elaborate that the Higgs mode, which develops below Tc, couples to the mode already developed below T*, resulting in an energy level splitting. The strong coupling effect offers new insight into the interplay between superconductivity and pseudogap. The result suggests that the pseudogap phase is not likely a precursor of superconductivity but represents a distinct order.

Work done with J. Y. Yuan, T. Dong, L. Yue, B. H. Li, Z. X. Wang, L. Y. Shi, S. J. Zhang, X. Y. Zhou, Y. Wang, Z. Z. Gan, K. Jin.

Visualizing the atomic and molecular orbital basis for pair formation in cuprate

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The parent compound of cuprate high temperature superconductors is a charge-transfer-type Mott insulator with strong hybridization between the Cu $3d_{x2-y2}$ and O 2p orbitals. A key question concerning the pairing mechanism is the behavior of doped holes in the antiferromagnetic (AF) Mott insulator background, which is a prototypical quantum many-body problem. Scanning tunneling microscopy (STM) represents an ideal experimental technique to address these questions owing to its capability of atomic-scale imaging of local electronic states.

In this work, we use STM to visualize the electronic structure of diluted holes doped into the $Ca_2CuO_2Cl_2$ parent Mott insulator of cuprates. We find that a single hole exhibits an in-gap electronic state and clover-shaped spatial distribution reminiscent of an extended d_{x2-y2} atomic orbital. For multiple dopants lying in close proximity, the overlap of wavefunctions generates stripe- and ladder-shaped molecular orbitals, accompanied by the opening of a precursory energy gap around the Fermi level. With increasing doping, the molecular patterns proliferate in space and gradually form densely packed plaquettes with characteristic length scale around 4 a_0. A full-fledged superconducting gap develops smoothly on top of the molecular orbitals, and display a systematic evolution of gap function. These results demonstrate that the stripe-like molecular orbital is the first low energy electronic state induced by doping the antiferromagnetic Mott insulator, and a local Cooper pair is formed by two holes occupying a molecular plaquette.

Laser ARPES on Pairing Symmetry and Electronic Origin of High-Tc in High Temperature Superconductors

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We will report our recent laser-based angle-resolved photoemission (ARPES) studies of the iron-based and cuprate superconductors. 1. We carried out ultra-high resolution ultra-low temperature (<1 K) laser ARPES measurements on KFe_2As_2 which is a prototypical iron-based superconductor with hole pockets both around the zone center and around the zone corners[1]. We have determined the superconducting gap distribution and identified the locations of the gap nodes on all the Fermi surface. The pairing symmetry in KFe_2As_2 is found to be of the s+- type. These results unify the pairing symmetry in the hole-doped iron-based superconductors and point to the spin fluctuation as the pairing glue in generating superconductivity. 2. We find that the electrons are coupled simultaneously with two sharp boson modes with energies of ~70meV and ~40meV in different cuprate superconductors with different doping levels, over the entire momentum space and at different temperatures above and below the superconducting transition temperature[2]. These comprehensive results provide a unified picture of the two energy scales and key information to understand the role of the electron-mode couplings in cuprate superconductors. 3. We observed for the first time the trilayer splitting in Bi2223 superconductor[3]. The observed Fermi surface, band structures, superconducting gap and the selective Bogoliubov band hybridizations can be well described by a three-layer interaction model. The electronic origin of the maximum Tc in Bi2223 and the persistence of the high Tc in the overdoped region is revealed. These results provide key insights in understanding high Tc superconductivity and pave a way to further enhance Tc in the cuprate superconductors.

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Scaling relations to link the strange metal state and superconductivity in overdoped cuprates

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For a cuprate system $La_{2-x}Ce_xCuO_4$, we developed advanced high-throughput techniques and used a combinatorial library to map how superconducting properties and normal-state properties of the superconductor evolve with minute compositional variation. A scaling relation between the superconducting transition temperature (Tc) and the slope of the T-linear resistivity (A_1) was disclosed for the first time, that is, $Tc \sim A_1^{1/2}$[Nature, 602, 431 (2022)]. This scaling relation was soon verified in FeSe via electric-field gating technique integrated with two-coil mutual inductance and electrical transport property measurements [Nature Phys. 19, 365 (2023)]. This unexpected universal scale indicates that there is a common origin of superconductivity in high-Tc superconductors, which bridges the strange metal state and the superconductivity. I will also present some other interesting scaling relations among penetration depth, coherent length and Tc.

Spin-orbit coupling and superconducting stripes in an oxide heterostructure EuO/KTO(110)

Xiangyu Hua, Zimeng Zeng, Fanbao Meng, Zongyao Huang, Xuanyu Long, Zhaohang Li, Shuai Wang, Zhengyu Wang, Tao Wu, Binghui Ge, Zhengyu Weng, Zheng Liu, Ziji Xiang, and Xianhui Chen

University of Science and Technology of China

Unconventional quantum states have been realized at the interfaces of oxide heterostructures, where they can be effectively tuned by the gate voltage. Recent studies reveal that the conductive interfaces in the $SrTiO_3$ (STO)-based and $KTaO_3$ (KTO)-based heterojunctions host a surprisingly enriched cascade of intriguing physical phenomena, most notably the emergence of two-dimensional (2D) superconductivity. Such 2D superconductivity is characterized by a Berezinskii-Kosterlitz-Thouless (BKT) transition; its unusual behavior in external magnetic fields and large tunability under varying electric fields render the superconducting oxide interfaces a promising platform for exploring the mechanism of unconventional superconductivity.

In this talk I will introduce our recent progress on the study of the interface between high-quality EuO (111) thin film and KTO (110) substrate. Both oxides are insulating, yet the interface is metallic and shows superconductivity with onset transition temperature Tc^{onset} =0.6-1.4 K depending on the carrier density. The 2D nature of superconductivity is verified by the large anisotropy of the upper critical field and the characteristics of a BKT transition. By applying gate voltages, Tc^{onset} can be largely tuned with an enhancement of ~70%; such an enhancement can be possibly associated with a boosted spin-orbit coupling (SOC) energy. Further analysis based on the upper critical field (Hc_2) and magnetoconductance reveals complex nature of SOC at the EuO/KTO (110) interface with different dominant scattering mechanisms in the superconducting and normal states. Our results demonstrate that the SOC should be considered an important factor in determining the 2D superconductivity at oxide interfaces.

More interestingly, we discovered a peculiar band-filling-controlled dimension reduction at the superconducting interface between EuO and (110)-oriented KTO. In devices with low carrier densities, electrical transport measurements reveal different Tc and Hc_2 with current applied along the two orthogonal in-plane directions. Theoretical analysis suggests that strong coupling between Ta *5d* and Eu *4f* electrons occurs in the low-carrier-density samples, whereas in the high-carrier-density samples (wherein Tc becomes isotropic) such coupling is weakened. These observations are likely to imply unprecedented spontaneous emergence of superconducting stripes, in which the phase coherence is established at a higher temperature than the rest of the interface. We propose that the realization of such superconducting stripes is closely related to the proximity coupling between superconductivity and the ferromagnetism in the EuO overlayer. Moreover, the *T*-linear in-plane Hc_2 observed in the low-carrier-density devices hints at unconventional nature of the interface superconductivity. Our findings may shed light on the long-mysterious interplays between the high-*Tc* superconductivity and the stripe order in copper oxide superconductors.

Electronic and magnetic excitations of (La, Ca)NiO_2 and $La_3Ni_2O_7$

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The discovery of unconventional superconductivity in infinite-layer (IL) nickelates, and the recent striking discovery of high-temperature superconductivity (HTSC) of 80 K in a bilayer nickelate $La_3Ni_2O_7$ under a moderately high pressure of about 14 GPa ignited a new wave of studying HTSC in nickelates.

1. For the IL case, the lack of direct measurements of the electronic structure over the past 5 years has hindered the understanding of its physics. Here, we fill this gap by preparing IL $LaNiO_2$ and $La_{0.8}Ca_{0.2}NiO_2$ thin films with superior surface quality and measuring their electronic structure by angle-resolved photoemission spectroscopy (ARPES). The Fermi surface consists of a large 3D hole pocket primarily contributedby Ni-3dx_{2-y2} states, and a small electron pocket at the Brillouin zone (BZ) corner. The hole pocket exhibits a 2D character over ~ 80% of the BZ, and its Fermi surface and band dispersion closely resemble those observed in hole-doped cuprates, suggesting their superconducting mechanisms may be alike. Yet this hole pocket shows strong three-dimensional character near kz = π, which deviates from previous calculations and adds new facets to the superconductivity in IL nickelates. The experimental electronic structure represents a pivotal step toward a microscopic understanding of the IL nickelate family and its superconductivity. [1]

2. For $La_3Ni_2O_7$, the properties of the parental phase at ambient pressure may contain key information on basic interactions therein and bosons that may mediate pairing. Moreover, the bilayer structure of La_3Ni2O_7 may suggest a distinct minimal model in comparison to cuprate superconductors. Using X-ray absorption spectroscopy and resonant inelastic X-ray scattering, we studied $La_3Ni_2O_7$ at ambient pressure, and found that Ni $3d_{x^{2-}y^{2}}$, Ni $3d_{z^2}$, and ligand oxygen 2p orbitals dominate the low-energy physics with a small charge-transfer energy. Remarkably, well-defined optical-like magnetic excitations were found to soften into a quasi-static spin-density-wave ordering, evidencing the strong electronic correlations and rich magnetic properties. Based on a Heisenberg spin model, we found that the inter-layer effective magnetic superexchange interaction is much larger than the intra-layer ones, and proposed viable magnetic structures. Our results set the foundation for further exploration of $La_3Ni_2O_7$ superconductor. [2]

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2024年浙江关联物质国际研讨会

2024 ZHEJIANG WORKSHOP ON CORRELATED MATTER

Abstracts of Posters

ID 001

Unconventional Hall effects in a quasi-kagome Kondo Weyl semimetal candidate

Yongkang Luo

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It is generally believed that electronic correlation, geometric frustration, and topology, individually, can play a midwife's role in easing the birth of various intriguing properties that have attracted a broad audience for both fundamental research and potential applications. Here, we report a systematic investigation on the unconventional Hall effects in a quasi-kagome Kondo Weyl semimetal candidate. The main findings of our work are: (1) In the paramagnetic state well above the Kondo scales, the observed AHE can not be described by a regular incoherent skew scattering (or side jump) predicted for most Kondo lattice systems; (2) In the magnetically ordered state, on top of the THE that is commonly seen in noncolinear spin systems, unprecedented loop-shaped THE (LTHE) with switching chirality is also seen; (3)The topological nature of this compound is supported by DFT calculations. These peculiar results suggest an extended global phase diagram for heavy-fermion systems and thus invoke further consideration about the mechanism of unconventional Hall effects in systems where topology, electronic correlation and geometrical frustration meet.

I D 002

Superconductivity in doped triangular Mott insulators: the roles of parent spin backgrounds and charge kinetic energy

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Kavli Institute for Theoretical Sciences, University of Chinese Academy of Sciences

We study the prerequisites for realizing superconductivity in doped triangular-lattice Mott insulators by considering three distinct parent spin backgrounds, i.e., 120 degree antiferromagnets, quantum spin liquid, and stripy antiferromagnets, and all possible sign combinations (τ1,τ2) of nearest-neighbor hopping and next-nearest-neighbor hopping (t1,t2). Based on density-matrix renormalization group calculations, we find that, with finite t2 and specific sign combinations (τ1,τ2), the quasi-long-range superconductivity order can always be achieved, regardless of the nature of the parent spin backgrounds. Besides specific hopping signs (τ1,τ2), these superconductivity phases in triangular lattices are commonly characterized by short-ranged spin correlations and two charges per stripe. In the robust superconductivity phase realized at larger t2/t1, flipping the signs τ2 and τ1 gives rise to the stripe phase without strong pairing and pseudogap-like phase without Cooper-pair phase coherence, respectively.

Interestingly, the roles of the two hopping signs are switched at smaller t2/t1. Moreover, different sign combinations (τ1,τ2) would stabilize distinct phases including superconductivity, charge density waves, spin density waves, and pseudogap-like phases accordingly. Our findings suggest the important role of charge kinetic energy in realizing superconductivity in doped triangular-lattice Mott insulators.

I D 003

Perturbation Theory of Single Particle Spectrum of Antiferromagnetic Mott Insulating States in the Hubbard Models

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In this work, we present an analytical framework for studying antiferromagnetic (AFM) Mott insulating states in the Hubbard model. We first derive an analytical solution for the single-particle Green's functions in the atomic limit. Within a second-order perturbation approach, we compute the ground state energy and show that the ground state is antiferromagnetically ordered. Then we derive an analytical solution for single-particle Green's functions when effects of the hopping term are considered in the Néel state. With the analytical solution, we compute and explain various properties of antiferromagnetic Mott insulators observed both experimentally and numerically: i) magnetic blueshift of the Mott gap; ii) spectral functions with features comparable to observations by angle-resolved photoemission spectroscopy on parental compounds of cuprate high Tc superconductors. This work comprehends the electronic properties of antiferromagnetic Mott states analytically and provides a foundation for future investigations of doped antiferromagnetic Mott insulators, aiming for the mechanism of cuprates high-Tc superconductivity.

I D 004

A mean-field study of quantum oscillations in two-dimensional Kondo insulators

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Max Planck Institute for the Structure and Dynamics of Matter

Magnetic oscillations in strongly correlated insulating systems have garnered interest due to oscillations seemingly originating from the bulk, despite an anticipated gapped spectrum. We use the large-N mean-field theory to study the behavior of normal and topological Kondo insulators under a magnetic field. In both cases spinons acquire a charge and hybridize with electrons, producing magnetic oscillations that resemble two-band noninteracting systems. We show that in such band insulators magnetic oscillations are exponentially suppressed at weak magnetic fields. A self-consistent mean-field calculation for the Kondo insulators reveals that the temperature dependence of the oscillations departs from the noninteracting case due to the temperature and magnetic-field dependence of the hybridization, even though mean-field parameters remain homogeneous. Higher temperature results in the Kondo breakdown, where the magnetic oscillation is solely due to the decoupled conduction electrons. These findings offer new insights into the magnetic properties of Kondo insulators, with implications for interpreting experimental results in heavy fermion materials like SmB6.

ID 005

Field-linear anomalous Hall effect and Berry curvature induced by spin chirality in the kagome antiferromagnet Mn3Sn

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During the past two decades, it has been established that a non-trivial electron wave-function topology generates an anomalous Hall effect (AHE), which shows itself as a Hall conductivity non-linear in magnetic field. Here, we report on an unprecedented case of field-linear AHE. In Mn3Sn, a kagome magnet, the out-of-plane Hall response, which shows an abrupt jump, was discovered to be a case of AHE. We find now that the in-plane Hall response, which is perfectly linear in magnetic field, is set by the Berry curvature of the wavefunction. The amplitude of the Hall response and its concomitant Nernst signal exceed by far what is expected in the semiclassical picture. We argue that magnetic field induces out-of-plane spin canting and thereafter gives rise to nontrivial spin chirality on the kagome lattice. In band structure, we find that the spin chirality modifies the topology by gapping out Weyl nodal lines unknown before, accounting for the AHE observed. Our work reveals intriguing unification of real-space Berry phase from spin chirality and momentum-space Berry curvature in a kagome material.

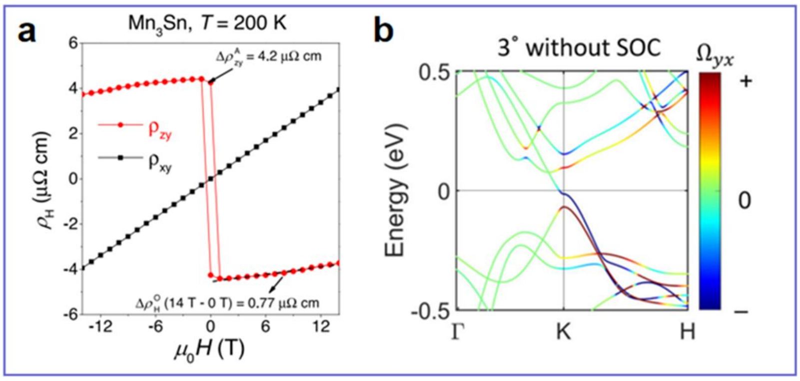

Figure 1: Field-induced linear anomalous Hall effect (a) and spin-chirality-induced Berry curvature (b) in the kagome antiferromagnet Mn_3Sn.

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ID 006

Semimetallic Kondo lattice behavior in YbPdAs with a distorted kagome structure

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Rare-earth compounds with the hexagonal ZrNiAl-type structure (space-group P 6 2m, No. 189), where magnetic rare earth atoms form a distorted kagome sublattice, exhibit a range of frustration induced behaviors, such as partial or dering [1], noncollinear magnetism [2], and spin ice states [3]. In Ce- and Yb- based compounds of this structure, remarkable manifestations of the interplay between magnetic frustration and the Kondo effect have been revealed [4-8].

We have synthesized YbPdAs with the hexagonal ZrNiAl-type structure in which the Yb atoms form a distorted kagome sublattice in the hexagonal-basal plane. Magnetic, transport, and thermodynamic measure ments indicate that YbPdAs is a low-carrier Kondo lattice compound with an antiferromagnetic transition at TN = 6.6 K, which is slightly suppressed in applied magnetic fields up to 9 T. The magnetic entropy at TN recovers only 33% of Rln2, the full entropy of the ground-state doublet of the Yb-ions. The resistivity displays a −TlnT dependence between 30 and 15 K, followed by a broad maximum at Tcoh = 12 K upon cooling. Below Tcoh, the magnetoresistance changes from negative to positive, suggesting a crossover from single-ion Kondo scattering processes at intermediate temperatures to coherent Kondo lattice behaviors at low temperatures. Both the Hall resistivity measurements and band-structure calculations indicate a relatively low carrier concentration in YbPdAs. Our results suggest that YbPdAs could provide an opportunity for examining the interplay of Kondo physics and magnetic frustration in low carrier systems.

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ID 007

Frustrated Altermagnetism and Charge Density Wave in Kagome Superconductor $CsCr_3Sb_5$

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Using first-principles density functional calculations, we investigate the electronic structure and magnetism of the kagome superconductor CsCr3Sb5. At the ambient pressure, its ground state is found to be 4x2 altermagnetic spin-density-wave (SDW) pattern, with an averaged effective moment of 1.7 μB per chromium atom. The magnetic long-range order is coupled to the lattice structure, generating 4a0 structural modulation. However, multiple competing SDW phases are present and energetically very close, suggesting strong magnetic fluctuation and frustration. The electronic states near the Fermi level are dominated by Cr-3d orbitals, and the Kagome flat bands are closer to the Fermi level than those in the AV3Sb5 family. When external pressure is applied, the energy differences between competing orders and the structural modulations are suppressed by external pressure. The magnetic fluctuation remains present and important at high pressure because the non-magnetic phase is unstable up to 30 GPa. In addition, a bonding state between Cr-3dxz and SbII-pz quickly acquires dispersion and eventually becomes metallic around 5 GPa, leading to a Lifshitz transition. Our findings strongly support unconventional superconductivity in the CsCr3Sb5 compound above 5 GPa, and suggest crucial role of magnetic fluctuations in the pairing mechanism

关键词：Kagome Superconductor，Altermagnetism

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ID 008

Flat-Band Enhanced Antiferromagnetic Fluctuations in Kagome Superconductor CsCr3Sb5

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The interrelationship between flat bands and correlated phenomena such as unconventional superconductivity stands as an intriguing subject in condensed matter physics. Here in Kagome superconductor CsCr3Sb5, we propose a sublattice-momentum-coupling-driven mechanism for the flat-band induced selective enhancement of antiferromagnetic fluctuations. By first-principles calculations and random phase approximation analyses, we manifest strong antiferromagnetic spin fluctuations in CsCr3Sb5, which is significantly contributed by the unoccupied incipient flat bands. The antiferromagnetic spin fluctuations then mediate two sets of spin-singlet superconducting orders with s±- and (dxy, dx2−y2)-wave symmetries. Further calculations in Kagome Hubbard model indicate that the sublattice-momentum-coupling-driven mechanism could widely exist in in Kagome systems where the Fermi level resides between flat bands and dispersive bands. Our work provides a new perspective for future studies of geometrically frustrated systems.

Keywords: Kagome system, spin fluctuation, unconventional superconductivity

ID 009

Inverse-current quantum electro-oscillations in a charge-density-wave insulator

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Quantum magneto-oscillations have long been a vital subject in condensed matter physics, with ubiquitous quantum phenomena and diverse underlying physical mechanisms. Here, we demonstrate the intrinsic and reproducible DC-current-driven quantum electro-oscillations with a periodicity in the inverse of the current (1/I), in quasi-one-dimensional charge-density-wave (CDW) insulators (TaSe4)2I and TaS3 nanowires. Such oscillations manifest in the nearly infinite Fröhlich conductivity region where the undamped CDW flow forms in a finite electric current, and finally disappear after the oscillation index n reaches 1. A systematic investigation on the effect of temperature and magnetic field establishes that the observed electro-oscillations are a coherent quantum phenomenon. We discuss the possibilities of the physical mechanisms, including the formation of sliding-driven inherent Floquet sidebands. Our results introduce a new member in the family of quantum oscillations, and shed light on plausible avenues to explore novel physics and potential applications of coherent density-wave condensates.

keywords：quantum electro-oscillations, charge-density-wave insulator, 1/I oscillations

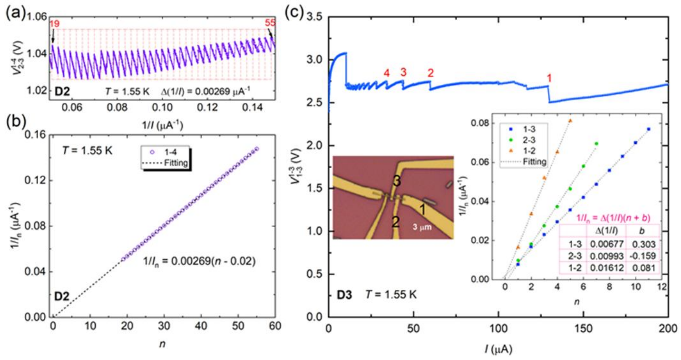

FIG. 1. (a) V_{2-3}^{1-4} vs. $1/I$ for $(TaSe_4)_2I$ nanowire device D3 at 1.55 K with a period of $\Delta(1/I)$ ~0.00269 μA^{-1}. (b) $1/I_n$ plotted against oscillation index n. (c) Current- and voltage-driven *V-I* curves at 1.55 K for D1. The inset shows $1/I_n$ vs. n for $V_{1-3}^{1-3}-I$, $V_{2-3}^{2-3}-I$ and $V_{1-2}^{1-2}-I$. Black dashed lines in (b) and (c) represent a linear fit to the data.

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ID 010

Emergence of Loop Current Order in the spinless Kagome Hubbard model

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Recent discoveries in kagome materials have unveiled their capacity to habor exotic quantum states, including intriguing superconductivity, charge density wave (CDW) and nematicity. Notably, accumulating experimental evidence suggests time-reversal symmetry (TRS) breaking within the CDW, hinting the long-pursued loop current order (LCO). Despite intensive investigations, the origin and mechanism of the CDW remained elusive. In this work, we comprehensively explore the competing electronic instabilities in the spinless kagome lattice at the van Hove filling with nonlocal Coulomb interactions, based on unbiased functional renormalization group calculations. We reveal that the second nearest-neighbor (nn) repulsion can promote fluctuations of imaginary bond charge order, driven by the sublattice interference and the lattice's unique geometry. This leads to a 2×2 LCO state primarily manifesting on second nn bonds, which prevails over a substantial parameter space when the second nn repulsion is notably strong. Remarkably, this TRS breaking LCO characterized by nontrivial Chern bands, reminiscent of the Haldane model, is identified for the first time at the van Hove filling through rigorous many-body

calculations. Additionally, the nematic CDW is favored at weak and strong interaction regimes, while the real charge bond order is predominant in the nn interaction dominant regime. We further discuss potential experimental implications of ours findings on the correlated phenomena in kagome metals. Our results shed light on the intricate quantum charge fluctuations inherent to the kagome lattice, highlighting the kagome metals as an ideal platform to explore the exotic correlated phenomena.

Key words: kagome metals, sublattice interference, loop current order, time-reversal symmetry breaking, unconventional superconductivity

Acknowledgement: We acknowledge the supports by the Ministry of Science and Technology (Grant No. 2022YFA1403901), National Natural Science Foundation of China (No. 11920101005, No. 11888101, No. 12047503, No. 12322405, No. 12104450) and the New Cornerstone Investigator Program. X.W. is supported by the National Key R\&D Program of China (Grant No. 2023YFA1407300) and the National Natural Science Foundation of China (Grant No. 12047503).

ID 011

Tuning the BCS-BEC crossover of electron-hole pairing with pressure

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In graphite, a moderate magnetic field confines electrons and holes into their lowest Landau levels. In the extreme quantum limit, two insulating states with a dome-like field dependence of the their critical temperatures are induced by the magnetic field. Here, we study the evolution of the first dome (below 60 T) and under hydrostatic pressure up to 1.7 GPa. With increasing pressure, the field-temperature phase boundary shifts towards higher magnetic fields, yet the maximum critical temperature remains unchanged. According to our fermiology data, pressure amplifies the carrier density and the effective mass. Thanks to this information, we verify the persistent relevance of the BCS relation between the critical temperature and the density of states in the weak-coupling boundary of the dome. In contrast, the strong-coupling summit of the dome does not show any detectable change with pressure. We argue that this is because the out-of-plane BCS coherence length approaches the interplane distance that shows little change with pressure. Thus, the BCS-BEC crossover is tunable by pressure, but with a locked summit.

ID 012

Purity-dependent Lorenz number, electron hydrodynamics and electron-phonon coupling in WTe_2

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Recently, thermal transport in both WP_2 and in Sb has been studied in order to detect signatures of hydrodynamics. These are expected when a significant portion of collisions between particles conserve momentum instead of relaxing it. This idea was first put forward, decades ago by Gurzhi, who proposed the possibility of viscous flow of electrons in metals and phonons in insulators. A renewal of interest in this topic has led to the experimental scrutiny of thermal transport by electrons and by phonons, as well as a number of theoretical studies.Here, we present a study of electrical and thermal transport in Weyl semimetal WTe_2 down to 0.3 K. The Wiedemann–Franz law holds below 2K and a downward deviation starts above. The deviation is more pronounced in cleaner samples, as expected in the hydrodynamic picture of electronic transport, where a fraction of electron-electron collisions conserve momentum. Phonons are the dominant heat carriers and their mean-free-path do not display a Knudsen minimum. This is presumably a consequence of weak anharmonicity, as indicated by the temperature dependence of the specificheat. Frequent momentum exchange between phonons and electrons leads to quantum oscillations of the phononic thermal conductivity. Bloch-Grüneisen picture of electron-phonon scattering breaks down at low temperature when Umklapp phonon-phonon collisions cease to be a sink for electronic flow of momentum. Comparison with semi-metallic Sb shows that normal phonon-phonon collisions are amplified by anharmonicity. In both semimetals, at cryogenic temperature, electron-phonon collisions degrade the phononic flow of energy but not the electronic flow of momentum.

Keywords: Wiedemann–Franz law, thermal conductivity, phonon, electron

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ID 013

Observation of Yu-Shiba-Rusinov-like states at the edge of $CrBr_3/NbSe_2$ heterostructure

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The interplay of magnetism and superconductivity induces a wealth of novel quantum states, such as high-temperature superconductivity, Fulde-Ferrel-Larkin-Ovchinnikov (FFLO) state and possibly, topological superconducting states. If magnetic impurities are arranged in high-density chains, individual YSR states will overlap and hybridize, possibly forming extended Shiba bands. Electrons in such Shiba bands may hybridize with the condensate of bulk superconductor by Andreev reflection, whose strength depends on the magnetic structure of the impurity chain. Assuming a helical or ferromagnetic arrangement of impurity spins, it is argued that an effective topological superconducting phase, akin to one-dimensional (1D) spinless p-wave superconductors, can be realized, with Majorana zero modes (MZMs) residing at the ends of the magnetic chain. Subsequently, this strategy has been successfully extended to two dimensions (2D). When magnetic adatoms are arranged in a 2D lattice on the surface of a superconductor with strong spin-orbit coupling, a 2D topological chiral p-wave superconductor with 1D dispersive Majorana edge modes will be realized.

Recently, signatures of 1D chiral Majorana edge modes were reported in the heterostructure fabricated by ferromagnetic $CrBr_3$ monolayer film grown on $NbSe_2$, manifested as a zero-energy conductance peak distributed discontinuously along the edges of $CrBr_3$ island. Being topologically protected, the Majorana edge states are generally considered to be insensitive to lattice defects or disorder, thus they should be spatially continuous along the edges. Therefore, the reported discrete Majorana edge modes in $CrBr_3/NbSe_2$ heterostructure are beyond the conventional understanding. To elucidate the anomalous phenomena, we construct $CrBr_3/NbSe_2$ heterostructures, and study them using scanning tunneling microscopy/spectroscopy (STM/STS) with high spatial and energy resolution. We find that the $CrBr_3$ film is insulating and acts as a vacuum barrier, the superconducting gap and vortex states measured on it are nearly identical to those of $NbSe_2$ substrate. Two types of edge states, one with a zero-energy conductance peak and the other with a pair of particle-hole symmetric in-gap bound states, are discretely distributed at the edges of $CrBr_3$ film. Their appearance is found to be closely related to the specific lattice reconstructions of the step edges. Moreover, tunneling transmissivity-dependent measurements find obvious evolution of these edge states as their exchange coupling strength J varies, resembling the properties of conventional YSR states. Our results provide conclusive experimental evidence for the topologically trivial origin of edge states in $CrBr_3/NbSe_2$ heterostructure, and the detailed structural and electronic information help further understand the interfacial coupling effect.

ID 014

Synthesis and physical properties of $Ln_2Rh_{3+\delta}Sb_4$ (Ln = Ce and La, δ = 0.12) single crystals

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We studied the physical properties of a new dense Kondo-lattice compound $Ce_2Rh_{3+\delta}Sb_4$ and its counterpart $La_2Rh_{3+\delta}Sb_4$, by a combination of electric transport, magnetic, and thermodynamic measurements. They crystallize in the orthorhombic $Pr_2Ir_3Sb_4$-like structure, with the space group Pnma (No. 62). $Ce_2Rh_{3+\delta}Sb_4$ shows a resistivity anisotropy $\rho_{a,b}/\rho_c \sim 2$, manifesting a quasi-one-dimensional electronic character. A long-range antiferromagnetic transition occurs at T_N = 1.4 K, while clear short-range ordering can be detected well above T_N. Kondo scale is estimated to be about 2.4 K, comparable to the strength of magnetic exchange. In contrast, $La_2Rh_{3+\delta}Sb_4$ has a superconductivity transition with onset transition at $T_c^{on} \approx 0.8$ K. Band structure calculations confirm it as a multi-band metal with a van-Hove singularity like feature at the Fermi level, whose density of states are mainly of Rh-4d and Sb-5p characters. Ultra-low temperature magnetic susceptibility and specific heat measurements suggest that it is an s-wave type-II superconductor. These results provide two $Ln_2Tm_{3+\delta}Sb_4$ (*Ln* = rare earth, *Tm* = Rh, Ir) family materials which may host new material bases for further investigations on electronic correlation, quantum criticality, and new superconductors

ID 015

^{27}Al NMR study of the magnetic Weyl semimetal CeAlGe

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Recently, band-topology-mediated magnetism in Weyl semimetals has inspired fast growing interest for both fundamental research and potential applications. Motivated by the recent observations of electronic correlation effect and topology-stabilized magnetic fluctuations in the noncentrosymmetric magnetic Weyl semimetal candidate CeAlGe, we performed systematic studies on the local static and dynamic spin susceptibilities by 27Al nuclear magnetic resonance. Due to the large spin susceptibility from Ce-4f electrons, the theoretically predicted responses from Weyl fermions are overwhelmed. A Knight-shift anomaly is observed below T∗∼ 50 K, a signature of the onset of coherent Kondo coupling. In addition, an anomalous peak is found in 1/T1T near 15 K, well above the magnetic ordering temperature TN ≈ 5 K, which probably is a consequence of topology-stabilized magnetic fluctuations. These results highlight the interplay among electronic correlation, magnetism and band topology in this family of Kondo Weyl semimetals.

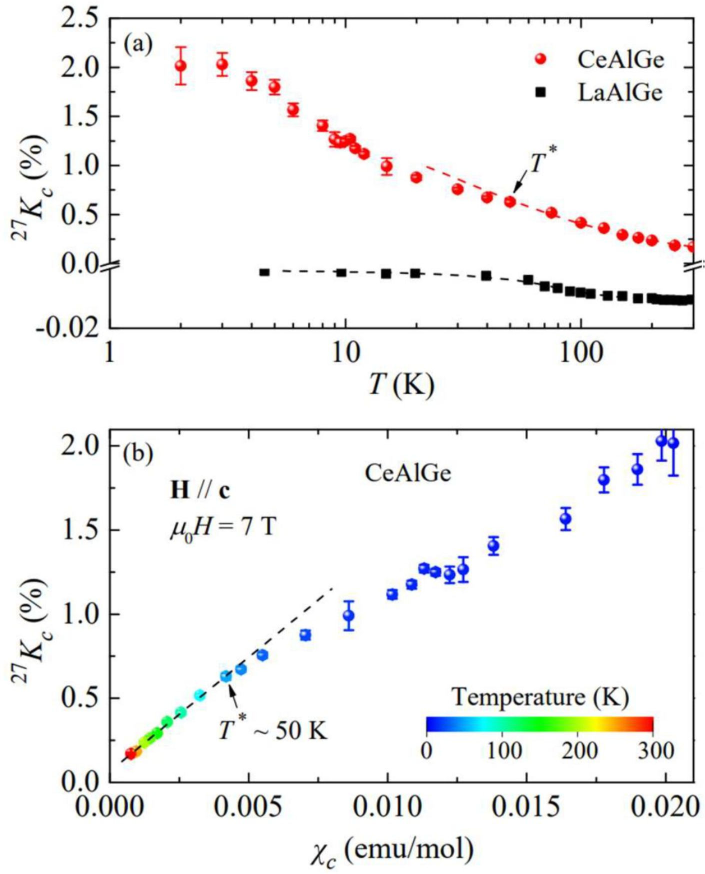

Fig 1. (a) Temperature dependence of 27Al NMR shift in CeAlGe. The data of LaAlGe are reproduced from Ref. [4]. (b) The Clogston-Jaccarino plot 27K vs. χ with T as an implicit parameter. The Knight-shift anomaly near 50 K is ascribed to Kondo coherence.

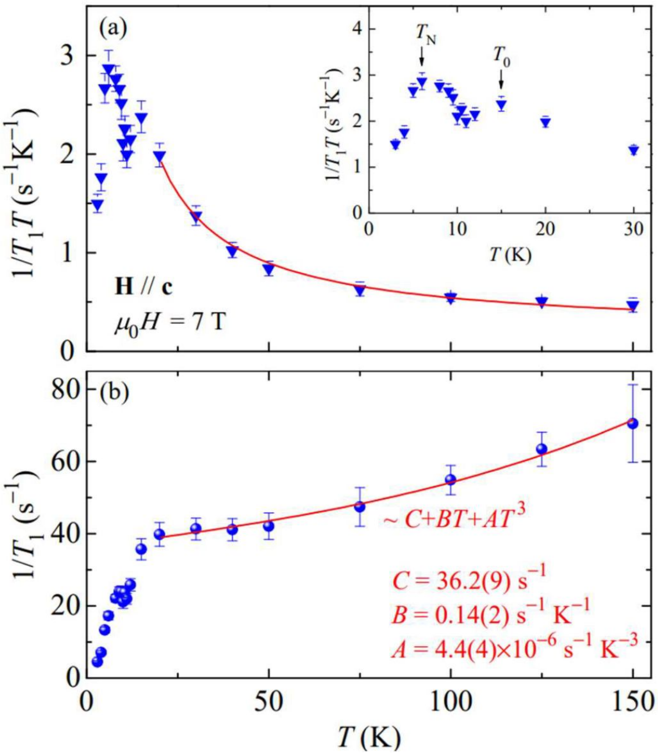

Fig 2. Spin-lattice relaxation rate of CeAlGe. (a) T dependence of 1/T1T. The solid line is a Curie-Weiss fitting. Inset, a zoom-in view to show the features around TN and T0.
(b) 1/T1 as a function of T. The high-T part of 1/T1 can be fitted to a C + BT + AT3 law.

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ID 016

Correlated BCS wavefunction approach to unconventional superconductors

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Abstract: We propose a modified BCS wavefunction as the ground state of a correlated superconductor with the correlation specified between k and -k electrons in the reciprocal space. Owing to this correlation, low-energy excitations are not conventional BCS Bogoliubov quasiparticles. They display at least four poles in the Green's function and their particle-hole weights in the tunneling and photon-emission spectrum become asymmetric. The superfluid stiffness also deviates from the BCS predictions with finite paramagnetic terms inside the total diamagnetic response. Moreover, a d-wave correlated pairing state becomes robust against weak disorders. Hence, this state can explain some mysterious features observed in unconventional superconductors like cuprates.

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ID 017

Thermal transport studies in high-Tc superconductor striped cuprates

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1/8 doped cuprates such as $La_{1.7}Eu_{0.2}Sr_{0.1}CuO_4$ (LESCO) and $La_{1.48}Nd_{0.4}Sr_{0.12}CuO_4$ (LNSCO), also called stripe cuprates, are ideal candidates for understanding the ground state properties of underdoped cuprates with intertwined orders, thanks to the strong correlation between the superconductivity (SC) and spin/charge orders in these materials. Experimentally, these materials are also preferred because they feature very low TC and therefore relatively small magnetic field (*H*) can be used to suppress SC, revealing their underlying ground states. Previous work reported that Hall signal (*R*H) of striped cuprates vanishes in a large phase space where SC is suppressed by *H*. Such observation is not likely from the cancellation of electron and hole pocket, but instead suggests an approximate particle-hole symmetry in these “anomalous” normal state, the nature of which requires further investigation.

In recent years, due to its sensitivity to charge-neutral excitations, thermal transport is often used to study novel physical phenomena in strongly correlated systems. Therefore, to reveal the nature of the “anomalous” normal state, we have conducted systematic studies of thermal transport properties in LESCO and LNSCO around 1/8 doping in extreme conditions of low temperature and high magnetic fields. The experimental results of the in-plane and out-plane thermal conductivity (κ_{xx} and κ_{xy}) and thermoelectric coefficients (Seebeck and Nernst effects) in these two materials will be presented and discussed.

ID 018

Exotic charge density waves and superconductivity on the Kagome Lattice

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Recent experimental investigations have identified fascinating electronic orders in kagome materials, such as intriguing superconductivity, charge density wave (CDW) and nematicity. Significantly, there is evidence of spontaneous time-reversal symmetry breaking within the CDW phase, though its origins remain elusive. In this work, we comprehensively explore the competitive instabilities in the spinless kagome lattice with inter-site Coulomb interactions at the van Hove filling. Through the analysis of charge susceptibility, we find that, at the nesting vector, the onsite charge order will be significantly suppressed, while the bond charge order gets enhanced owing to the sublattice texture on the Fermi surface. We also observe that next nearest-neighbor (NN) bonds are characterized by significant intrinsic imaginary bond fluctuations. The 2×2 loop current order emerges as the ground state when the next NN repulsion is strong. While, sufficiently strong inter-site interactions give rise to a nematic state with unit cell charge density modulations. We further explore the possible superconductivity away from van Hove filling, where $p -$ and $f -$ wave pairings appear from bond charge fluctuations.

ID 019

UnXonventional superconductivity in Cr-based compound $Pr_3Cr_{10}{-}xN_{11}$

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Specific heat and muon spin relaxation (μSR) measurements on a polycrystalline sample of Pr3Cr10−xN11, which shows superconducting state below Tc = 5.25 K, a large upper critical field Hc2 ~ 20 T and a residual Sommerfeld coefficient γ0, will be reported. The field dependence of γ0(H) resembles γ of the U-based superconductors UTe2 and URhGe at low temperatures. The temperature dependent superfluid density measured by transverse-field μSR experiments is consistent with a p-wave pairing symmetry. ZF-μSR experiment suggests a time-reversal symmetry broken superconducting transition, and temperature independent spin fluctuations at low temperatures is revealed by LF-μSR experiments. These results indicate that Pr3Cr10−xN11 is a candidate of p-wave superconductor which breaks time-reversal symmetry.

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ID 020

Emergent Loop current order in the Kagome lattice

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Recent experimental investigations have identified fascinating electronic orders in kagome materials, such as intriguing superconductivity, charge density wave (CDW) and nematicity[1-5]. Notably, there is evidence of spontaneous time-reversal symmetry (TRS) breaking within the CDW phase, though its origins remain elusive. In this work, we comprehensively explore the competitive instabilities in the kagome lattice with nonlocal interactions at the van Hove filling. We thoroughly analyze in intrinsic onsite and bond charge fluctuations within the kagome lattice, uncovering their intimate relations with the sublattice texture on the Fermi surface[6-8]. We find that, at the nesting vector, the onsite charge order will be significantly suppressed, while the bond charge order get enhanced owing to the sublattice interference effects. We also observe that next nearest-neighbor bonds are characterized by significant intrinsic imaginary bond fluctuations. The 2x2 loop current order(LCO) emerges as the ground state when the next NN repulsion is strong. Moreover, this TRS breaking LCO characterized by nontrivial Chern bands, reminiscent of the Haldane model, is also identified through rigorous many-body calculations. While, sufficiently strong nonlocal interactions give rise to a nematic sublattice CDW. We further explore the possible superconductivity deviating from van Hove filling, where p- and f -wave pairings appear from bond charge fluctuations. Potential experimental implications are also discussed.

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ID 021

Trion states of attractive SU(3) ultracold fermions in optical lattices

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We study the trion formation and its effects on quantum criticality and finite-temperature properties of the half-filled attractive SU(3) Hubbard model on a honeycomb lattice by performing the quantum Monte Carlo (QMC) simulation. In the charge density wave (CDW) phase, we show that on-site and off-site trions coexist and the off-site trion forms a local bond state. The critical exponents determined by the QMC simulation remarkably disagree with those of the N=3 chiral Ising universality class suggested by the effective Gross-Neveu-Yukawa theory, but coincide with the N=1 chiral Ising universality class. As the Hubbard |U| increases at low temperatures, the system first undergoes a transition from thermal Dirac semimetal to CDW, and eventually the CDW state is thermally melted at strong coupling where the system enters the liquid phase of on-site trions. In the trion CDW states where off-site trions arise from quantum fluctuations, the simulated triple occupancy at constant Hubbard |U| surprisingly increases with temperature, implying that the formation of off-site trions is suppressed by the thermal delocalization of on-site trions. We find that the critical exponents of the thermal CDW transition points vary along the phase boundary, accompanied by the density variation of the off-site trions. We have also calculated the entropy-temperature relations for various attractive Hubbard interactions, which exhibit the prominent characteristic of the Pomeranchuk effect.

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ID 022

Direct observation of the 4f-electron properties in the ferromagnetic Kondo lattice $CeAgSb_2$

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The localized-to-itinerant transition of f-electrons plays a crucial role in understanding the exotic properties in heavy fermion (HF) system. In Kondo lattice model, f electrons are localized at high temperature and become itinerant at low temperature. However, there are still some controversies about this process, such as how to accurately define the onset temperature of forming the heavy quasiparticles. Here, the electronic structure and 4f-electron properties in ferromagnetic Kondo lattice $CeAgSb_2$ are comprehensively studied, using high-resolution angle-resolved photoemission spectroscopy (ARPES). The variation in spectral weight of the quasiparticle band at different momentum locations indicates that c-f hybridization has a strong momentum dependent feature. The temperature-dependent study of Ce 4f state reveals the localized-to-itinerant transition of f electrons and the characteristic temperature (~ 100 K) of forming the heavy quasiparticles, which is much higher than the coherence temperature. Our results provide generalized microscopic experimental picture of the f-electron behavior in $CeAgSb_2$ and a microscopic understanding of energy scale in the heavy fermion system.

ID 023

Anisotropic magnetic properties of antiferromagnetic $DyCoGa_5$

Jiyuan Li

We report a detailed study of the physical properties of single crystals of $DyCoGa_5$ using magnetic susceptibility, specific heat, and resistivity measurements. $DyCoGa_5$ crystallizes in the layered tetragonal $HoCoGa_5$-type structure and undergoes two successive antiferromagnetic transitions at T_{N1} = 24.7 K and T_{N2} = 22.9 K, which are associated with ordering of the Dy3+ moments. We characterize the temperature-field phase diagrams of $DyCoGa_5$ for fields both along the c axis and within the ab plane, where highly anisotropic magnetic behaviors are observed. When fields are applied along the easy c axis, both T_{N1} and T_{N2} are suppressed with increasing field, and multiple metamagnetic transitions are observed, while these transitions exhibit only a weak field dependence for H || ab. From our analysis we propose a crystalline-electric-field scheme that gives rise to the observed Ising anisotropy, and a simple model of the magnetic exchange interactions can account for the low-temperature antiferromagnetic phase, as well as the field-induced phase with a magnetization half the saturated value

ID 024

Quasiparticle multiplets and 5f itinerant-localized crossovers in Pu_3Ga

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The high-temperature δ phase of plutonium can be stabilized at room temperature by doping it with a few percent gallium, and the cubic phase Pu_3Ga plays a crucial role in understanding the mechanism of the stabilized δ phase of plutonium-gallium alloy. In this study, we discovered that the spectral weights of 5f electrons in Pu_3Ga are reduced compared to δ -Pu, suggesting the increased localization of 5f electrons that promotes the stability of Pu_3Ga. Through a comprehensive investigation of the temperature-dependent correlated electronic states of Pu_3Ga using a combination of the density functional theory and the embedded dynamical mean-field theory, we found that the enhanced localization of 5f states at high temperatures is accompanied by depressing quasiparticle resonance peaks and weakened valence fluctuations. Moreover, the quasiparticle multiplets resulting from the many-body transitions among the $5f^4$, $5f^5$, and $5f^6$ electronic configurations collapse as temperature increases. The hybridizations between the 5f bands and conduction bands also decrease at high temperatures, causing changes in the Fermi surface geometry indicative of a temperature-driven electronic Lifshitz transition. Finally, the calculated linear specific heat coefficient γ is approximately 112 mJ/(mol×K^2) at 80 K, suggesting that Pu_3Ga could be a promising candidate of plutonium-based heavy-fermion system.

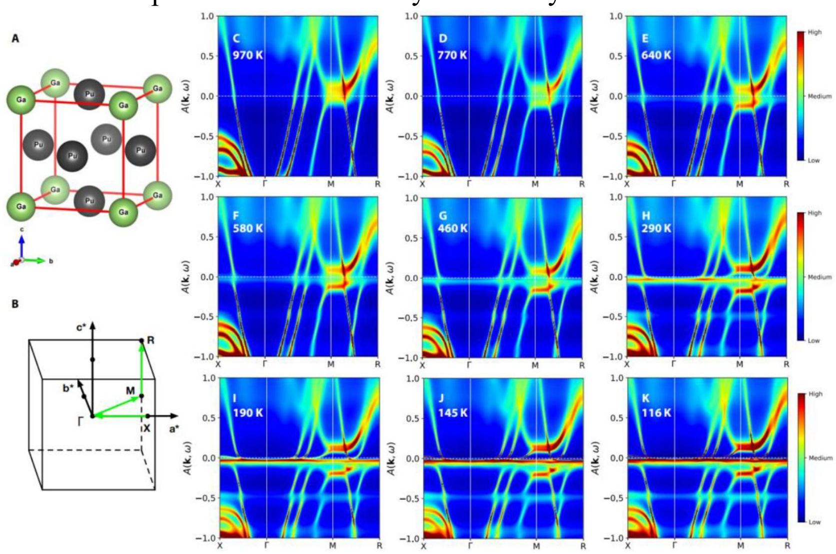

Figure 1: Crystal structure and temperature-dependent quasiparticle band structures of cubic phase Pu_3Ga.

ID 025

Uniaxial-strain tuning of electronic orders and spin excitations in $FeSe_{1-x}S_x$

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$FeSe_{1-x}S_x$ undergoes a structural transition without the existence of antiferromagnetic order, which provides an excellent platform for exploring the origin of electronic nematicity and its interplay with other orders and fluctuations. We use the inelastic neutron scattering and resonant inelastic X-ray scattering to investigate electronic orders and spin excitations anisotropy in FeSe and $FeSe_{1-x}S_x$ ($0 \leq x \leq 0.21$) under uniaxial strain.

We find that the stripe spin excitations (Q = (1, 0)/(0, 1)) exhibit the C_2 symmetry up to $E \approx$ 120 meV, while the Néel spin excitations (Q = (1, 1)) retain their C_4 symmetry in the nematic state in detwinned FeSe. The temperature dependence of the difference in the spin excitations at Q = (1, 0) and (0, 1) for temperatures above the structural phase transition unambiguously shows the establishment of the nematic quantum disordered state. The similarity of the Néel excitations in FeSe and NaFeAs suggests that the Néel excitations are driven by the enhanced electron correlations in the $3d_{xy}$ orbital. We find that the stripe spin excitations (Q = (1, 0)/(0, 1)) exhibit the C_2 symmetry up to $E \approx 120$ meV, while the Néel spin excitations (Q = (1, 1)) retain their C_4 symmetry in the nematic state. The temperature dependence of the difference in the spin excitations at Q = (1, 0) and (0, 1) for temperatures above the structural phase transition unambiguously shows the establishment of the nematic quantum disordered state. The similarity of the Néel excitations in FeSe and NaFeAs suggests that the Néel excitations are driven by the enhanced electron correlations in the $3d_{xy}$ orbital.

We use resonant inelastic x-ray scattering (RIXS) at the Fe-L_3 edge to study the spin excitations of uniaxial-strained and unstrained $FeSe_{1-x}S_x$ ($0 \leq x \leq 0.21$) samples. The measurements on unstrained samples reveal dispersive spin excitations in all doping levels, which show only minor doping dependence in energy dispersion, lifetime, and intensity, indicating that high-energy spin excitations are only marginally affected by sulfur doping. RIXS measurements on uniaxial-strained samples reveal that the high-energy spin-excitation anisotropy observed previously in FeSe is also present in the doping range $0 < x \leq 0.21$ of $FeSe_{1-x}S_x$. The spin-excitation anisotropy persists to a high temperature up to T > 200 K in x = 0.18 and reaches a maximum around the nematic quantum critical doping ($x_c \approx 0.17$). Since the spin-excitation anisotropy directly reflects the existence of nematic spin correlations, our results indicate that high-energy nematic spin correlations pervade the regime of nematicity in the phase diagram and are enhanced by the nematic quantum criticality.

ID 026

Spin dynamics in detwinned $KFe_{0.8}Ag_{1.2}Te_2$

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Electronic nematicity, the breaking of rotational symmetry driven by an electronic degree of freedom, is both immensely interesting in its own right and has garnered recent attention due to its commonality in the vicinity of unconventional superconductivity. Electronic nematic order dominates the phase diagram of iron-based superconductors and its fluctuations proliferate near optimal superconductivity, suggesting it to be an essential aspect of the unconventional superconducting state.

$KFe_{0.8}Ag_{1.2}Te_2$ is supposed to be a good platform for investigating the nematic order in the localized limit. Using inelastic neutron scattering, we have measured the spin dynamics in detwinned $KFe_{0.8}Ag_{1.2}Te_2$ to study the spin-nematicity arising from the local moment magnetism.

ID 027

WannSAGE: A Wannier-Based Software Package for Symmetry Adapted Superconducting Gap Equations

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The extensive investigations of unconventional superconductors have posed challenges to the theoretical tools for handling complicated systems. Here we introduce a software package WannSAGE, which efficiently solves the linearized superconducting gap equations within the random phase approximation and spin-fluctuation mediated pairing scenario. In WannSAGE, we start from the high-quality first-principles normal state electronic model, calculate the spin and charge correlation functions, then construct and solve symmetry adapted gap equations for superconductors. WannSAGE capitalizes on the merits of the system symmetry, in which the k mesh, Hamiltonian, correlation functions, and superconducting gaps are all well reduced and symmetrized. In the aspect of performance, most calculations in WannSAGE are done in parallel, with various specialized optimizations for multi-band systems. Besides, WannSAGE also offers diverse utilities for data processing and visualization, which brings great convenience to our studies on superconductors.

Keywords: unconventional superconductivity, spin fluctuation, random phase approximation, symmetry

ID 028

Exploring Fermi Surface Nesting and the Nature of Heavy Quasiparticles in the Spin-Triplet Superconductor Candidate $CeRh_2As_2$

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In this study, we investigate the electronic structure of a spin-triplet superconductor candidate $CeRh_2As_2$ using high-resolution angle-resolved photoemission spectroscopy and density functional theory calculations. Notably, Fermi surface nesting hints at connections to magnetic excitation or quadrupole density wave phenomena, elucidating the superconducting mechanisms. Measured band structures reveal primarily localized 4 f electrons, with minor itinerant contributions. Additionally, a transition from localized to itinerant behavior and significant c-f hybridization anisotropy underscore the role of f-electrons in shaping electronic properties. These findings deepen our understanding of $CeRh_2As_2$'s unconventional superconductivity and magnetism. Further exploration promises advances in superconductivity research.

ID 029

The magnetic ground state of the interlayer coupled 1T-TaS_2

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1T-TaS_2 experiences a series of phase transitions upon cooling and enters an insulating state with star of David (SOD) patterns. Theoretically, this insulating state in a single layer with an orphan spin is expected to form a quantum spin liquid state (QSL). Given that QSL suggests a potential territory for searching high-temperature superconductivity and quantum computation, 1T-TaS_2 generates intense interests. However, some studies have indicated that the bilayer coupling in bulk 1T-TaS_2 prevents the formation of Mott insulators. The question of whether the bulk 1T-TaS_2 is a realistic QSL is still highly debated. In order to gain further insight, we performed a systematic ^{33}S NMR experiment on single crystal 1T-TaS_2, which is sensitive to the stacking patterns and the low-energy spin excitations. The NMR spectra demonstrate that the SOD pattern is already present in the nearly commensurate charge density wave (CDW) phase and that the bilayer coupling occurs in the commensurate CDW phase. Furthermore, the temperature-dependent spin-lattice relaxation rate $1/T_1$ indicates that the spin excitations in bulk 1T-TaS_2 should be fully gapped. Moreover, the Knight shift and $1/T_1T$ indicate a modified Korringa relation, which unambiguously rules out the existence of the spinon Fermi surface or Dirac spinon in the bulk 1T-TaS_2. Meanwhile, the further simulation of the Knight shift and $1/T_1$ indicates that the insulating state in the commensurate CDW phase can be explained by a semiconductor model. The present work not only reveals the magnetic ground state in bulk 1T-TaS_2 but also suggests the importance of the interlayer interaction in two-dimensional Van der Waals materials.

ID 030

Ultrafast Dynamics Study of Nickel Oxide Superconductor $La_4Ni_3O_{10}$

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The discovery of superconductivity in bulk nickel oxide materials $La_{n+1}Ni_nO_{3n+1}$ (n=2, 3) under high pressure provides a novel research platform for exploring the mechanism of high-temperature superconductivity. Specifically, $La_4Ni_3O_{10}$, which has been reported to exhibit density wave order under ambient pressure, gradually suppresses its density wave order as pressure increases, and superconductivity emerges. This transition is strikingly similar to the process of suppressing antiferromagnetic order through doping in copper-based and iron-based superconducting materials, leading to the induction of superconductivity [1-3]. To further explore the formation mechanism of density wave order in $La_4Ni_3O_{10}$ and its intrinsic relationship with superconductivity, we employed ultrafast spectroscopy to conduct a detailed study of the quasiparticle dynamic relaxation process under ambient pressure. Experimental results indicate a significant and rapid increase in relaxation time near the temperature of the density wave order phase transition, suggesting a possible gap opening at this phase transition temperature. Additionally, by fitting the relaxation time variation with temperature using the Rothwarf-Taylor (RT) model, we successfully obtained the specific size of this gap. Notably, our experiments also observed pronounced oscillations in the time evolution of the reflectivity of $La_4Ni_3O_{10}$. After subtracting the exponential relaxation background, we applied Fourier transformation to the extracted oscillatory signals and identified multiple coherent oscillation modes. Among them, the most prominent mode with a frequency of approximately 3.8 THz was defined as the A_{1g} mode. As temperature increases, most oscillation modes exhibit a gradual decrease, or red shift. Particularly noteworthy is the significant change in high-frequency oscillation modes near the density wave order phase transition temperature, suggesting a close association with the formation of density wave order. Our study provides crucial insights and evidence for elucidating the origin of density wave order in $La_4Ni_3O_{10}$, potentially paving a new path for a deeper understanding and application of high-temperature superconductivity mechanisms.

Key word：Nickel oxide superconductors, Ultrafast Spectroscopy, Density wave

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ID 031

Pressure tuned transmutation of the spin-orbit intertwined nematicity in FeSe

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In high-temperature superconductors (HTSCs), diverse symmetry-breaking electronic orders exhibit intricate intertwinements, thereby giving rise to kinds of intertwined orders. As vestigial or composite order, various electronic nematicity have arouse great research interest, since they expose signatures of the underlying physics of the intertwined order, and can be effectively tuned by hydrostatic pressure p (or uniaxial strain ε). Here, we focus on the evolution of the electronic nematicity in iron-based superconductor (IBSC) FeSe under finely varying hydrostatic p. Through comprehensive ^{57}Fe and ^{77}Se nuclear magnetic resonance (NMR) study, we observe mutable orbital ingredients in forming the electronic neamticity. With increasing p, the role played by d_{xy} orbital become more and more important, accompanied with an enhanced spin-correlation anisotropy, which finally results in a transmutation of the electronic nemticity. The overall phase diagram at low-p region show a crossover behavior. Above a characteristic p (p_{c1}~0.6 GPa), a short-range magnetic order (SRMO) emerges and manifests itself on the significantly anisotropic broadening of the ^{57}Fe NMR spectra, while completely absent in the ^{77}Se NMR spectra. Our findings reveal a tunable intertwinement between spin- and orbital-driven nematicity, and provide key insights for establishing a universal picture of the electronic nematicity and its correlations with magnetism and superconductivity in IBSCs.

ID 032

Diverging Grüneisen Ratio in a Strange Ferromagnetic Metal

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Universality is a key concept underpinning phase transitions, whereby disparate systems exhibit common behaviors irrespective of their microscopic degrees of freedom. This principle extends to quantum phase transitions driven by quantum fluctuations at low temperatures, where the dynamical exponent z effectively increases the dimensionality of these fluctuations. Identifying the critical exponents associated with hitherto unexplained quantum critical phenomena, such as ferromagnetic quantum criticality and strange metallicity with Planckian dissipation [1], is vital for revealing their origin. Here, we report measurements of the Grüneisen ratio at a ferromagnetic quantum critical point exhibiting strange metal behavior [2], which reveal the presence of a $z = 3$ dynamical critical exponent. Though these results initially appear to align with an itinerant ferromagnetic quantum critical point [3], they are inconsistent with the presence of strong magnetic anisotropy and the lack of inversion symmetry in the crystal structure. These seemingly conflicting experimental findings are reconciled by identifying this exponent as the signature of a hidden charge mode corresponding to amplitude fluctuations of the hybridization, which serves as the Higgs mode of the Kondo breakdown transition. These insights provide the framework for understanding the mechanisms giving rise to quantum criticality in ferromagnets and in other systems with uniform order parameters. Moreover, these results underscore the pivotal role of charge modes in realizing strange metals near quantum critical points in a more diverse range of systems, highlighting the intertwining of quantum

criticality associated with charge and magnetic degrees of freedom.

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ID 033

Orientation-dependent Superconductivity and Electronic Structure of the Rare-earth Metal/$KTaO_3$ Interfaces

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The recent discovery of orientation-dependent superconductivity in $KTaO_3$-based interfaces has attracted considerable interest, while the underlying origin remains an open question. Here we report a different approach to tune the interfacial electron gas and superconductivity by forming interfaces between rare-earth (RE) metals (RE being La, Ce, Eu) and $KTaO_3$ substrates with different orientations. We found that the interfacial superconductivity is strongest for the Eu/$KTaO_3$ interfaces, becomes weaker in La/$KTaO_3$ and is absent in Ce/$KTaO_3$. Using in-situ photoemission, we observed distinct valence bands associated with RE metals, as well as a pronounced orientation dependence in the interfacial electronic structure, which can be linked to the orientation-dependent superconductivity. The photoemission spectra show similar double-peak structures for the (111) and (110) oriented interfaces, with an energy separation close to the LO4 phonon of $KTaO_3$. Detailed analyses suggest that this double-peak structure could be attributed to electron-phonon coupling, which might be important for the interfacial superconductivity.

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ID 034

3d flat bands and coupled 4f moments in the kagome-honeycomb permanent magnet Sm_2Co_{17}

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Hybrid ferromagnets with coupled local-moment and itinerant components are not only interesting due to the rich physics, but also important for applications such as rare earth permanent magnet (REPM). Flat bands generated by destructive interference in special lattices offer additional opportunities to realize strong ferromagnetism. Here, by combining molecular beam epitaxy and angle-resolved photoemission spectroscopy, we report observation of 3d flat bands near the Fermi level (E_F) in a prototypical strong REPM Sm_2Co_{17}, which has a kagome-honeycomb lattice. Two sets of flat bands, one at ~ -300 meV and the other right at E_F, arise from orbital-selective destructive interference in the kagome-honeycomb lattice and strong correlation effects from Co 3d electrons. Our results further unveil that Sm 4f electrons are mostly localized and exhibit an anomalous temperature evolution, due to the 3d-4f interaction and competition with ferromagnetism. Our work provides spectroscopic insight to understand the hybrid ferromagnetism in REPMs. Our study also opens up opportunities to find and tune flat bands in correlated kagome-honeycomb lattices.

ID 035

Muon spin relaxation study of the layered kagome superconductor CsV_3Sb_5

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The Z_2 topological metals RV_3Sb_5 (R = K, Rb, Cs) with a layered kagome structure provide a unique opportunity to investigate the interplay between charge order, superconductivity, and topology. Here, we report muon-spin relaxation/rotation (μSR) measurements performed on CsV_3Sb_5 across a broad temperature range, in order to uncover the nature of the charge density wave order and superconductivity in this material. From zero-field μSR, we find that spontaneous magnetic fields appear below 50 K, which is well below the charge density wave transition ($T^* \sim 93$ K). We show that these spontaneous fields are dynamic in nature making it difficult to associate them with a hidden static order. The superconducting state of CsV_3Sb_5 is found to preserve time-reversal symmetry, and the transverse-field μSR results are consistent with a superconducting state that has two fully open gaps.

ID 036

Superconductivity of cerium at quasihydrostatic pressure up to 54 GPa

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Cerium is a fascinating element due to its diverse physical properties, which include forming various crystal structures (γ, α, α', α'', and ϵ), mixed valence behavior, and superconductivity, making it an ideal platform for investigating the interplay between different electronic states. Here, we present a comprehensive transport study of cerium under quasihydrostatic pressures up to 54 GPa. Upon applying pressure, cerium undergoes the $\alpha \rightarrow \alpha''$ transition at around 4.9 GPa, which is accompanied by the appearance of superconductivity with T_c of 0.4 K, and T_c slightly increases to 0.5 K at 11.4 GPa. At 14.3 GPa, T_c suddenly increases when the α'' phase transforms into the ϵ phase, reaching a maximum value of 1.25 K at around 17.2 GPa. Upon further increasing the pressure, T_c monotonically decreases. Together with the results of previous studies, our findings suggest that the evolution of superconductivity in cerium is closely correlated with the multiple pressure-induced structural transitions and corresponding unusual electronic structures.

ID 037

Competing charge-density wave instabilities in the Kagome metal ScV_6Sn_6

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Owing to its unique geometry, the kagome lattice hosts various many-body quantum states including frustrated magnetism, superconductivity, and charge-density waves (CDWs). In this work, using inelastic X-ray scattering, we discover a dynamic short-range $\sqrt{3}\times\sqrt{3}\times 2$ CDW that is dominant in the kagome metal ScV_6Sn_6 above $T_{CDW}\approx 91$ K, competing with the $\sqrt{3}\times\sqrt{3}\times 3$ CDW that orders below T_{CDW}. The competing CDW instabilities lead to an unusual CDW formation process, with the most pronounced phonon softening and the static CDW occurring at different wavevectors. First-principles calculations indicate that the $\sqrt{3}\times\sqrt{3}\times 2$ CDW is energetically favored, while a wavevector-dependent electron-phonon coupling (EPC) promotes the $\sqrt{3}\times\sqrt{3}\times 3$ CDW as the ground state, and leads to enhanced electron scattering above T_{CDW}. These findings underscore EPC-driven correlated manybody physics in ScV_6Sn_6 and motivate studies of emergent quantum phases in the strong EPC regime.

ID 038

Inelastic neutron scattering and muon spin relaxation investigations of the deuterated Kondo lattices $CeNiSnD_x$

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CeNiSn is a Kondo semimetal where a gap opens at low temperatures due to hybridization between 4*f* and conduction electrons, but a full insulating state fails to develop. Upon the insertion of hydrogen, long range magnetic order is induced. Here we report zero-field muon-spin relaxation and inelastic neutron scattering measurements of polycrystalline samples of the deuterides $CeNiSnD_x$ (x=1.0, 1.8). The muon-spin relaxation results confirm magnetic ordering in the whole sample of CeNiSnD below around 4.7 K, while inelastic neutron scattering reveals two well-defined crystalline electric field (CEF) excitations at around 13 meV and 34 meV in CeNiSnD, and 5 meV and 27 meV for $CeNiSnD_{1.8}$. These results suggest that hydrogenation leads to the localization of the Ce-4*f* electrons, giving rise to long-range magnetic order. We propose CEF level schemes for both systems, which predict a ground state moment of 0.96 μ_B/Ce within the *ab*-plane for $CeNiSnD_{1.8}$ and a saturated moment of 1.26 μ_B/Ce along the easy *c* axis for CeNiSnD, that account for the observed magnetic properties.

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ID 039

Large *g*-wave altermagnetic splitting near Fermi level in CrSb

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Recently, a new kind of magnetism, called altermagnetism, has attracted widespread interest. A key characteristic of altermagnet is the momentum-dependent band and spin splitting with zero net magnetization, in contrast with the ordinary ferromagnet and antiferromagnet, which can lead to novel spin-transport properties and interfacial superconductivity. Here we investigated the three-dimensional electronic structure of CrSb, a proposed bulk *g*-wave altermagnet, using synchrotron-based angle-resolved photoemission spectroscopy (ARPES) and density functional theory (DFT) calculations. Our ARPES measurements reveal the largest altermagnetic band splitting (~1.1eV) near the Fermi level (E_F) so far, with the k_z and in-plane momentum dependence that agrees very well with the DFT calculations, providing direct spectroscopic evidence for its bulk-type *g*-wave altermagnetism. The microscopic origin of the large altermagnetic splitting can be attributed to strong next-nearest-neighbor hopping mediated by Sb ions, based on analysis of the tight-binding model. The large band/spin splitting near E_F in metallic CrSb, together with its high T_N (705 K) and simple spin configuration, can be important for exploring emergent phenomena and realizing spintronics applications.

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ID 040

Topological diode effect on the surface of SmB_6

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Diodes based on semiconductor pn-junctions are a fundamental element in integratedcircuits of microelectronic devices. Current rectification, the ability to convert alternating electrical current to direct current, is a typical application of a diode. By applying radio frequency modulation, we observe a pronounced current rectification effects in SmB_6, a prototype topological Kondo insulator. Intriguingly, our experimental results and modeling uncover that this current rectification is intimately tied to the formation of topological surface states (TSS). Specifically, the phenomenon appears due to self-generated pn-junctions between puddles of metallic TSS regions, which results in broken mirror symmetry. Furthermore, the diode effect could be fine-tuned by tem- perature and suppressed by magnetic impurities. Our findings provide a novel example of a nonreciprocal diode effect of topological pn-junction based on three-dimensional topological insulators (3DTI). Such topological diode could serve as a current rectifier for radio frequency signal detectors or energy harvesting devices, pointing to exciting potential applications of 3DTI.

ID 041

Kagome materials AV_3Sb_5 (A=K,Rb,Cs): pairing symmetry and pressure-tuning studies

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The vanadium-based kagome metals AV_3Sb_5 (A = K, Rb, and Cs) host a superconducting ground state that coexists with an unconventional charge density wave (CDW). The CDW state exhibits experimental signatures of chirality, electronic nematicity, and time-reversal-symmetry breaking, raising the questions whether the superconductivity (SC) in AV_3Sb_5 may also be unconventional, how SC interplays with CDW, and how the two orders evolve upon tuning. We reviews studies of the superconducting pairing symmetry, and the tuning of SC and CDW in the AV_3Sb_5 compounds. Various experimental techniques consistently find that CsV_3Sb_5 exhibits nodeless SC, which remains robust regardless whether the CDW is present. Under hydrostatic pressure, SC in AV_3Sb_5 becomes enhanced as the CDW is gradually suppressed, revealing a competition between the two orders. In CsV_3Sb_5, a new CDW state emerges under pressure that competes more strongly with SC relative to the CDW at ambient pressure, and results in two superconducting domes that coexist with CDW. After the CDW in AV_3Sb_5 is fully suppressed with hydrostatic pressure, a further increase in pressure leads to a nonmonotonic evolution of the superconducting transition temperature driven by lattice modulations. Thickness is shown to be a powerful tuning parameter in AV_3Sb_5 thin flakes, revealing the evolution of CDW and SC upon dimensional reduction, and can be combined with hydrostatic pressure to shed light on the interplay between SC and CDW. Based on the results reviewed, we discuss outstanding issues to be addressed in the AV_3Sb_5 systems.

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ID 042

High-temperature superconductivity with zero-resistance and strange metal behaviour in $La_3Ni_2O_{7-\delta}$

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Recent experimental observations have showed some signatures of superconductivity close to 80 K in $La_3Ni_2O_{7-\delta}$ under pressure, and have raised the hope of achieving high-temperature superconductivity in bulk nickelates [1]. However, a zero resistance state—a key characteristic of a superconductor—was not observed. Here, we show that the zero resistance state does exist in single crystals of $La_3Ni_2O_{7-\delta}$ using a liquid pressure medium at up to 30 GPa. We also find that the system remains metallic under applied pressures, suggesting the absence of a metal-insulator transition proximate to the superconductivity. Moreover, analysis of the normal state T-linear resistance reveals a link between this strange metal behaviour and superconductivity. The association between strange metal behaviour and high-temperature superconductivity is very much in line with other classes of unconventional superconductors, including the cuprates and Fe-based superconductors. Further investigations exploring the interplay of strange metal behaviour, superconductivity, as well as possible competing electronic or structural phases are essential to understand the mechanism of superconductivity in this system.

ID 043

Anisotropic magnetic property of single crystals *R*Rh6Ge4 (*R* = Pr, Nd, Sm, Gd- Er)

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Single crystals of RRh_6Ge_4 (R = Pr, Nd, Sm, Gd- Er) are synthesized using a Bi flux and their physical properties are characterized by magnetization, resistivity, and specific heat measurements. These compounds crystallize in the noncentrosymmetric $LiCo_6P_4$-type structure (space group $P\bar{6}m2$), where rare-earth atoms form a triangular lattice in the ab-plane and chains along the c-axis. $PrRh_6Ge_4$ and $ErRh_6Ge_4$ do not exhibit magnetic transitions above 0.4K. Magnetic susceptibility of moment bearing rare-earths R = Nd, Gd-Ho follow a Curie-Weiss behavior at high temperatures. For R = Nd, Sm, Tb- Ho, strong magnetic anisotropy is observed due to crystalline electric field effects. The easy magnetization direction is determined to be the c-axis for R = Nd, Gd- Ho and the ab-plane for R = Sm. $NdRh_6Ge_4$ and $SmRh_6Ge_4$ are ferromagnets and the other magnets show antiferromagnetic transitions. It is worth noting that for R = Tb- Ho, there is an additional transition below the Néel temperature as evidence from specific heat measurements. In addition, there is a clear deviation of the magnetic ordering temperature of $TbRh_6Ge_4$ from the de Gennes scaling, which might be related to its crystal field effect and complex magnetic properties.

ID 044

Multigap *s*-wave superconductivity emerging in the 1*T'* phase of MoTe2 under hydrostatic pressure

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Hydrostatic pressure transforms the superconductor MoTe2 from a type-II Weyl semimetallic *Td* phase to a topologically trivial 1*T'* phase at low temperature, serving as an ideal platform to explore the interplay between topology and superconductivity (SC). We report a soft point-contact-spectroscopy (SPCS) study on single-crystalline MoTe2 under hydrostatic pressure up to 2.5 GPa, where the local SC transition temperature *Tc* of MoTe2 in the contact region shows the same behavior as the reported pressure phase diagram. Excess current extracted from the integrated conductance subtracted by the normal state shows a positive correlation with the 1*T'* phase volume fraction as a function of pressure, supporting that the probed SC under pressure is mainly contributed by the 1*T'* phase of MoTe2. Our SPCS spectra are better fitted by a two-gap *s*-wave Blonder-Tinkham-Klapwijk model in the whole pressure range, yielding 2Δ1/*kBTc* = 2.0–2.5 and 2Δ2/*kBTc* = 4.15–5.0, respectively, and suggesting a strong-coupling SC for 1*T'* -MoTe2.

ID 045

Nodeless multigap superconductivity in organic-ion-intercalated $(TBA)_{0.3}FeSe$

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We probe the superconducting order parameter of the organic-ion-intercalated FeSe-based superconductor $(TBA)_{0.3}FeSe$ using muon-spin relaxation/rotation (μSR). Zero-field μSR measurements show only a weak temperature dependence with no evidence for magnetic ordering or broken time reversal symmetry in the superconducting state. The temperature dependence of the superfluid density is deduced from transverse-field μSR measurements with fields applied both parallel and perpendicular to the c-axis, and can be well described by a nodeless two-gap s + s model. These properties are reminiscent of those of $(Li_{1-x}Fe_x)OHFe_{1-y}Se$, which also has a comparably enhanced T_c, suggesting that such a gap structure is a common feature of this class of quasi-two-dimensional intercalated FeSe-based superconductors.

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ID 046

Suppression of ferromagnetism and influence of disorder in platinum-substituted $CeRh_6Ge_4$

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We report a study of isoelectronic chemical substitution in the recently discovered quantum critical ferromagnet $CeRh_6Ge_4$. Upon platinum doping, the ferromagnetic ordering temperature of $Ce(Rh_{1-x}Pt_x)_6Ge_4$ is continuously increased. The strange metal behavior was suppressed with the increasing doping concentration. While applied pressure on the compound with different doping, the transition temperature can be continuously depressed and T-linear behavior observed at high pressure. At critical pressure, the lowest temperature did not show T-linear behavior which is likely a consequence of the disorder induced by platinum doping. Our findings show the effects of disorder on the unusual ferromagnetic quantum criticality in $CeRh_6Ge_4$, and provide further evidence for understanding the origin of this behavior.

ID 047

Distinct pressure evolution of superconductivity and charge density wave in kagome superconductor CsV_3Sb_5 thin flakes

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It is intriguing to explore the coexistence and (or) competition between charge density wave (CDW) and superconductivity (SC) in many correlated electron systems, such as cuprates, organic superconductors, and dichacolgenides. Among them, the recently discovered Z_2 topological kagome metals AV_3Sb_5 (A = K, Rb, Cs) serve as an ideal platform to study the intricate relation between them. Here, we report the electrical resistance measurements on CsV_3Sb_5 thin flakes (≈60 nm) under hydrostatic pressure up to 2.12 GPa to compare its pressure phase diagram of CDW and SC with its bulk form. Even though the CDW transition temperature (T_{CDW}) in CsV_3Sb_5 thin flakes is still monotonically suppressed under pressure and totally vanishes at P_2 = 1.83 GPa similar to the bulk, the superconducting transition temperature (T_c) shows an initial decrease and consequent increase up to its maximum ~8.03 K at P_2, in sharp contrast with the M-shaped double domes in the bulk CsV_3Sb_5. Our results suggest the important role of reduced dimensionality on the CDW state and its interplay with the SC, offering a new perspective to explore the exotic nature of CsV_3Sb_5.

ID 048

High-sensitivity setup to measure transition and quantum oscillation under magnetic field

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Here, we present two powerful and high-sensitivity experiment method, tunnel diode oscillator (TDO) and dynamic magnetometer (tuning fork), which are capable to capture transition or quantum oscillation signal with high-resolution under magnetic field. TDO is a contactless measurement and more sensitive to change in resistance comparing to straight resistance measurement, and it can also be performed under high pressure condition. Tuning fork is a dynamic magnetic cantilever method, which can map the susceptibility tensor in a single experiment. We show some experiments here to manifest the high efficiency of these method.

ID 049

Evolution of superconductivity in $LaNiGa_2$ under pressure

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Here we present a transport study of single crystal $LaNiGa_2$ under pressure. The critical temperature (T_c) increases with pressure reaching a maximum value at 14.3 GPa, and decreases at higher pressures, while the upper critical field (Hc_2) monotonically increases. Hc_2 in the ac-plane are higher than those along the b-axis at all pressures examined. Our analysis suggests that the change of Hc_2 may be accounted for by the evolution of the electronic structure. In contrast, powder X-ray diffraction (XRD) results show no evidence for structural phase transitions up to 26.3 GPa. Moreover, Hall resistivity measurements under pressure shows a sign change of Hall coefficient near where Tc is maximum, as well as a pronounced enhancement of the magnitude of Hall coefficient, suggesting a possible pressure-induced Lifshitz transition that is closely linked to the enhancement of superconductivity. Interestingly, the angle-dependent Hc_2 in the ac-plane exhibits a peculiar symmetry that is independent of current direction and sample variability which provides further information on the evolution of superconductivity.

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