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Abstract Collection

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Revisiting magnetization plateaus in $\text{SrCu}_2(\text{BO}_3)_2$ by high-field NMR

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Investigation of magnetization plateaus in the Shastry-Sutherland compound $\text{SrCu}_2(\text{BO}_3)_2$ by high-field NMR at LNCMI-Grenoble now spans 25 years, during which these experiments marked some of crucial technical advances of the laboratory. The first ever ultra-high-field NMR measurement carried out in a dilution refrigerator [1] brought the experimental confirmation for the nature of the plateaus: the $^{63,65}\text{Cu}$ NMR spectrum recorded at 27.6 T and 35 mK evidenced the commensurate spin superstructure demonstrating the Wigner crystallization of magnetic excitations, taken to be the extended triplets at that time. As the field of 34 T became available, the first experiment carried out up to this field value was the ^{11}B NMR spectroscopy, establishing the precise sequence of the low-magnetization plateaus, at 1/8, 2/15, 1/6 and 1/4 of the saturation magnetization [2]. In the meantime, using advanced tensor-network numerical methods, theorists proposed that constituting elements of the 1/8, 2/15 and 1/6 plateaus are not the spin-1 extended triplets but the spin-2 bound triplet pairs forming a pinwheel pattern [3]. In 2025, by one of the two first experiments carried out in the new hybrid magnet of LNCMI, providing up to 42 T, we could compare the $^{63,65}\text{Cu}$ NMR spectrum in the 1/3 plateau at 41.9 T to the spectra in 27.6 T and 29.0 T, respectively in the 1/8 and 2/15 plateau. Confronting the spectra to the updated theoretical prediction for the spin superstructures, we proved that, as expected, the 1/3 plateau is based on the extended triplets and the 1/8 and 2/15 plateaus on the pinwheel-shaped spin-2 elements [4]. To our knowledge, this is the first ever real-space imaging of a complex, bound triplet pair excitation, demonstrating remarkable power of the NMR technique. Our results add the formation of Wigner crystals of bound states as a new paradigm in the theory of magnetization plateaus.

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NMR Probe for Spinon Excitations in Quantum Magnets

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Low-dimensional quantum magnetic materials with strong fluctuation effects host a rich variety of competing ground states. In the zero-temperature limit, external tuning parameters can drive the system into novel quantum phases or quantum critical regions, giving rise to emergent scaling behaviors and new types of excitations. An important frontier in this field is the search for fractionalized quantum excitations such as spinons, which provides a platform for discovering novel phenomena in solid-state materials and advancing scalable quantum technologies. In this talk, I will present our nuclear magnetic resonance (NMR) studies on several low-dimensional quantum magnets, exploring the possible existence of spinon excitations. Our key findings include: (1) In the one-dimensional Heisenberg chain compound copper benzoate, we found experimental evidence for spinons, spinon localization, and magnetic-field-induced solitons; (2) In the frustrated Shastry-Sutherland lattice material $\text{SrCu}_2(\text{BO}_3)_2$, we discovered magnetic-field-induced deconfined quantum critical phenomena between the plaquette singlet states and the antiferromagnetic phase, where unconventional scaling behavior supports the existence of novel elementary excitations; (3) In the spin-1/2 bilayer triangular lattice antiferromagnet $\text{Rb}_2\text{Co}_2(\text{SeO}_3)_3$, we identified a series of magnetic-field-induced candidate spin liquid states.

Wide-Field Optically Detected Magnetic Resonance under Pressure for Imaging
Superconductivity
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Optically detected magnetic resonance (ODMR) provides a spatially resolved magnetometer that images the local Meissner response inside the cell, as demonstrated for a hydride superconductor using diamond NV centers [1]. We are developing such a wide-field high-pressure ODMR platform, and this talk reports its design and present status. The motivation is the bilayer nickelates. $\text{La}_3\text{Ni}_2\text{O}_7$ superconducts under pressure up to ~ 80 K [2], but the superconducting fraction is often small. ^{139}La -NQR and NMR reveal the structural disorder, intergrowths, and density-wave order [3,4], yet cannot access the Meissner effect. However, our recent SQUID data show only 3% diamagnetic shielding above 20 GPa. I will discuss sensor implementation, wide-field diamagnetic mapping of YBCO and Pb, and the obstacles before reaching ~ 20 GPa, plus an AI-assisted autonomous platform unifying ODMR, NMR, and NQR.

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High-Pressure NMR and Quantum Sensing Enabled by Diamond Nitrogen-Vacancy Centers

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Quantum sensing refers to the use of quantum systems, quantum properties, or quantum phenomena to achieve highly sensitive detection of physical quantities. Among various physical systems, the nitrogen-vacancy center (NV center) in diamond has attracted significant attention in recent years. Its unique spin and optical properties enable sensitive measurements of magnetic fields, temperature, pressure and other parameters at the nanoscale. In addition, the exceptional mechanical and optical properties of diamond allow this quantum probe to operate over a wide range of environmental and even extreme conditions, such as ultralow (300 mK) or high (1400 K) temperatures, strong magnetic fields (~ 8.3 T) and high pressures (~ 140 GPa). This provides a unique tool for frontier studies in condensed matter physics, materials science and geoscience. In this talk, I will present recent experimental progress in diamond quantum sensing under high pressures, including HP-NMR enabled by NV centers, and probing the Meissner effect in bilayer nickelates ($\text{La}_3\text{Ni}_2\text{O}_7$) and lanthanum hydrides (LaH_{10}) with this quantum probe.

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Magnetic excitations above 1/3 magnetization plateau in kagome antiferromagnet

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Magnetic ground states in kagome antiferromagnets have been intensively studied to reveal the quantum mechanically disordered magnetic states. By applying high magnetic fields, further intriguing phenomena have been introduced such as the plateau in magnetization curve at the 1/9 of the full saturation value in $\text{YCu}_3(\text{OH})_{6.5}\text{Br}_{2.5}$. [S. Jeon (2024), S. Suetsugu (2024), G. Zheng (2025)]. Although higher magnetic fields induce another magnetization plateau at the 1/3 of the full saturation, the field strength required to access the 1/3 plateau is more than 50 T and is too large to perform most of the microscopic experiments. Thus, we focus on another Cu-based mineral $\text{InCu}_3(\text{OH})_6\text{Cl}_3$, which shows the 1/3 plateau around 10 T due to smaller energy scale of exchange interactions [M. Kato, (2024)]. This allows us to perform NMR experiments in the entire field range reaching the full saturation. The measured nuclear spin-lattice relaxation rate demonstrates that the magnetic excitations are gapped in the 1/3 plateau state and the gap size increases with fields [M. Kato (2025)]. We will also discuss the magnetic excitations above the 1/3 plateau based on the results obtained in the higher magnetic fields.



BKT correlations in the quantum kagome compound $\text{Cs}_2\text{Cu}_3\text{SnF}_{12}$

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Frustration is one of main topics of research in condensed matter physics, as this mechanism can lead to the emergence of a variety of ground states – from quantum spin-liquids and solids, superconductivity, to fractionalized excitations. $S = 1/2$ Heisenberg model on a kagome lattice is considered to host the highest level of frustration in 2D, with many ground states of nearly identical energy. Consequently, many kagome compounds have been synthesized and studied. It is therefore surprising that none of these was found to host Berezinskii-Kosterlitz-Thouless (BKT) correlations – interacting topological defects that exist exclusively in 2D systems. To date, BKT correlations have been reported in only a handful of systems, always confined to a narrow temperature range. We report the discovery of BKT fluctuations [1] in the kagome system $\text{Cs}_2\text{Cu}_3\text{SnF}_{12}$ using nuclear quadrupolar resonance (NQR). Fluctuations persist across a remarkably broad temperature range of over 100 K above the Néel temperature $T_N = 20$ K. Within the same temperature range, we observe increase in the NQR linewidth consistent with short-range chiral order recently identified by neutron scattering. Analysis of the local hyperfine fields below T_N indicates a spin structure consistent with P21/n symmetry of negative vector chirality. We show that BKT fluctuations are absent [2] in the sister compound $\text{Rb}_2\text{Cu}_3\text{SnF}_{12}$, opening a path for future study of BKT onset point through doping and/or pressure. Our results establish $\text{Cs}_2\text{Cu}_3\text{SnF}_{12}$ as a unique quantum kagome system exhibiting BKT behaviour.

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Design of a DDS-based high-field NMR spectrometer and its applications in quantum magnetic material research

Long Ma

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Nuclear magnetic resonance (NMR) is a powerful and distinctive probe for investigating quantum matter states and low-energy excitations under high magnetic fields. In this talk, I will first present a new design of high-performance NMR spectrometer based on direct digital synthesizer (DDS) and digital quadrature receiver developed for condensed matter physics research. This spectrometer covers an exceptionally broad frequency range from 1 MHz to over 1 GHz using only a few integrated chips. Importantly, the image spurious signals commonly encountered in analog quadrature demodulators are entirely eliminated through digital signal processing (DSP) embedded in the field-programmable gate array (FPGA). Second, I will report our comprehensive experimental results—including magnetization, torque magnetometry, specific heat, and NMR measurements—on the high field intermediate phase between the 1/3-magnetization plateau and polarized state in the quantum Ising antiferromagnet $\text{Rb}_2\text{Co}(\text{SeO}_3)_2$ with triangular lattice. The magnetic phase diagram with the magnetic field intensity up to 30 T is mapped by our experimental data.



Highly frustrated magnetism in Y-kapellasite under extreme conditions

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Y-kapellasite ($\text{Y}_3\text{Cu}_9(\text{OH})_{19}\text{Cl}_8$) materializes an anisotropic kagome antiferromagnet model with three different nearest neighbor interactions, yielding a rich phase diagram [1]. Besides two long range ordered collinear $Q = 0$ and coplanar $Q = (1/3, 1/3)$ phases, this phase diagram features a large spin liquid area, which encompasses the highly-studied isotropic kagome antiferromagnet model. Upon applied field, a $1/9$ -plateau in magnetization is observed, a long-sought feature predicted for the isotropic Kagome Heisenberg antiferromagnet model. We present a detailed investigation of large, phase pure, single crystals of this compound by local μSR and NMR techniques upon externally applied fields and hydrostatic pressure [2,3]. Well below the antiferromagnetic Curie-Weiss temperature of 100 K, Y-kapellasite shows a magnetic transition to the coplanar $(1/3, 1/3)$ long-range order at 2.1 K, as predicted theoretically [1,4]. However, our analysis of the excitations using linear spin-wave calculations yields a new estimate of magnetic interactions, which locate the compound closer to the phase boundary to the spin-liquid phase than expected from *ab initio* DFT calculations. Using hydrostatic pressure, we could establish that the fragile long-range order is suppressed in favor of a fluctuating ground state from μSR experiment. This finding is rationalized by new high pressure diffraction results showing a tendency towards a more isotropic lattice in the same range of applied pressures. Therefore, our results establish Y-kapellasite as a rare clean kagome material in which long-range order is suppressed by pressure-tuned frustration, the first fingerprint for the realization of a quantum spin liquid without strong disorder.

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Muon Site Dynamics Imitating Fractional Spin Excitations in a Quantum Spin Chain

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Fractional spin excitations in low-dimensional and frustrated magnets are commonly associated with sporadic spin fluctuations observed in spin liquids, spin ices, and other complex magnetic states. In this study, we investigate spin dynamics in the amplitude-modulated magnetic ground state of AgCuVO_4 , a spin-1/2 chain compound with competing intrachain interactions. Muon spin spectroscopy measurements reveal a Gaussian decay of muon polarization that remains remarkably resilient against applied magnetic fields---a behavior often interpreted as evidence of emergent sporadic spin dynamics. However, density functional theory calculations of muon stopping sites suggest an alternative mechanism: a two-state model in which the muon hops between two nearby sites, and finally equilibrates across both on a microsecond timescale. These findings provide a microscopic explanation for the field-resilient muon polarization and indicate that such behavior may not solely stem from intrinsic spin fluctuations, but can also result from muon site dynamics.



Structural Instabilities in $\text{Mn}_4\text{Nb}_2\text{O}_9$ and $\text{Co}_4\text{Nb}_2\text{O}_9$: Comparative Insights into the Role of Local Structure

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The ambient-, low-temperature, and high-pressure behaviors of the honeycomb-structured spin-driven magnetoelectrics $\text{Mn}_4\text{Nb}_2\text{O}_9$ (MNO) and $\text{Co}_4\text{Nb}_2\text{O}_9$ (CNO) are investigated using nuclear magnetic resonance (NMR), diffuse reflectance spectroscopy, Raman scattering, magnetic susceptibility, and synchrotron X-ray diffraction. Under ambient conditions, Raman and NMR spectra, alongside spin-lattice (T_1) and spin-spin (T_2) relaxation constants reveal significantly stronger local structural distortion in MNO than in CNO, despite their identical global crystal symmetries and band gaps. Both compounds exhibit pronounced spin-phonon coupling near their magnetic ordering temperatures. However, MNO uniquely displays a possible hidden structural transition, evidenced by a new high-frequency Raman mode alongside distinct anomalies in phonon frequencies and linewidths. This behavior is attributed to enhanced magnetic frustration and stronger local distortions inherent to MNO. This local disparity heavily influences their high-pressure structural evolutions. CNO undergoes three isostructural transitions at 5.2, 8.5, and 11.5 GPa before undergoing a long-range symmetry transition from the P-3c1 to the P2/c phase at 17 GPa. Conversely, MNO displays similar isostructural instabilities at lower pressures (2, 6.6, and 10 GPa) and switches to a distinct symmetry C2/c at 12.5 GPa. Crucially, high-pressure Raman spectra replicate several low-temperature anomalies—including phonon shifts, linewidths and new mode emergences within the 2–11.5 GPa range—signalling pressure-induced potential magnetic interactions. Rietveld refinement shows pronounced anisotropic lattice compression in both compounds, with differences of 20.5% in CNO and 42.5% in MNO between the compressibilities along the a- and c-axes. This anisotropic compression leads to a substantial reduction in the c/a ratio, which may enhance interlayer coupling and promote magnetic ordering under compression.

Intrinsic versus defect magnetism in a kagome quantum spin liquid

Andrej Zorko

Jožef Stefan Institute, Slovenia

Quantum spin liquids (QSLs), as highly entangled magnetic ground states that evade conventional symmetry-breaking order, have become a central theme in studies of quantum materials, with geometrically frustrated lattices such as the two-dimensional kagome network among the most promising realizations. A persistent challenge in the field is that many QSL candidates host magnetic defects that govern their low-energy behavior, yet the nature and role of the defects in stabilizing or destabilizing the QSL state remain poorly understood. This challenge is especially acute in the leading kagome candidates herbertsmithite and Zn-barlowite, where Cu/Zn site mixing places magnetic Cu^{2+} defects on the interlayer cation sites. Strikingly, the purest available samples across different groups exhibit a remarkably similar and surprisingly strong low-temperature magnetic response that appears inconsistent with their nominally high stoichiometric purity. Here we address this problem in Zn-barlowite by combining the local-probe sensitivity of ^{19}F nuclear magnetic resonance (NMR) with bulk magnetic measurements. Simultaneous modelling of experiments, backed up with density functional theory calculations, allows us to efficiently disentangle the responses of intrinsic kagome spins and defect spins and to determine their inherent behavior.



Persistent spin dynamics: What is going on?

Lei Shu

Fudan University, China

A wide variety of materials with no magnetic order down to the lowest temperature have shown muon relaxation rates which becomes a constant below a temperature of a few Kelvin and continues with that value down to the lowest temperature measurable as low as about 10 milli-Kelvin. Such a phenomena is often called persistent spin dynamics, firstly revealed by Uemura and collaborators more than 30 years ago. In this talk, results from different materials will be reviewed, theoretical understanding of this phenomenon is needed.

Magnetic properties and spin dynamics in $\text{Cu}_2(\text{OH})_3\text{Br}$

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We present comprehensive high magnetic field studies of the alternating weakly coupled ferro-antiferromagnetic (FM-AFM) spin-1/2 chain compound $\text{Cu}_2(\text{OH})_3\text{Br}$. Our measurements reveal a broad magnetization plateau at about half of the saturation value, in magnetic fields at least up to 50 T. We obtain the detailed phase diagram up to 14 T for three principal field directions (a , b , c^*), that clearly indicates suppression of magnetic ordering upon approaching this plateau. With the phase diagram in the magnetic field established, we proceed to the dynamic properties of $\text{Cu}_2(\text{OH})_3\text{Br}$. Our high-field ESR spectroscopy studies reveal a complex pattern of high-frequency spinon-magnon bound-state excitations. The existence of such states has been pointed out in previous zero-field inelastic neutron scattering measurements [Zhang et al., PRL 125, 037204 (2020)]. On the other hand, at lower frequencies we find two modes of antiferromagnetic resonance as a consequence of the long-range magnetic ordering. We obtain detailed frequency-field and temperature dependencies of all these excitations, that allow us to establish a clear difference in their nature and their respective roles in field-induced phase transitions.



Disorder as a tuning parameter in Kitaev Quantum Materials

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Layered transition-metal oxides provide a fertile ground for emergent quantum phenomena, where strong electronic correlations intertwine with geometry, frustration, and intrinsic disorder. Among the most elusive of these phases are quantum spin liquids, states in which magnetic moments remain entangled and fluctuate down to the lowest measured temperatures. Here, we will discuss how intrinsic disorder in layered honeycomb oxides reshapes the physics of these states, leading to unexpected forms of fractionalized spin excitations and novel quantum phases. Using the proximate Kitaev material $\text{Na}_2\text{Co}_2\text{TeO}_6$ as a case study, we will show how vacancies and local structural variations can drive the system into a regime where gapped and gapless fractional excitations coexist, consistent with a quantum Griffiths phase. Beyond the specific material, these results highlight a broader theme: disorder, often seen as detrimental, can act as a powerful tuning parameter for stabilizing new phases of correlated quantum matter.

Collaborating teams: W. Papawassiliou[1], A. J. Pell[1], N. Lazaridis[2], M. Fardis[2], and G. Papavassiliou*[2]

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From Antiferroelectricity to Low-Dimensional Magnetism: NMR Studies of CuCrP_2S_6 and AgCrP_2S_6

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Van der Waals chromium thiophosphates provide a rich platform for studying the interplay of low-dimensional magnetism, structural instabilities, and magnetic ordering. In this talk, I will present recent NMR studies of CuCrP_2S_6 and AgCrP_2S_6 , highlighting how local probes reveal their distinct spin correlations and ordered states. In AgCrP_2S_6 , magnetization and ^{31}P NMR measurements establish a quasi-one-dimensional $S=3/2$ Heisenberg antiferromagnet with strong intrachain correlations, and an unusual temperature evolution of the effective hyperfine coupling. Comparison with the prototypical Haldane-chain compound AgVP_2S_6 provides a useful benchmark for the spin dynamics of integer- and half-integer-spin chain systems. In CuCrP_2S_6 , ^{31}P and ^{65}Cu NMR directly track a sequence of antiferroelectric and antiferromagnetic phase transitions [1]. The measurements provide microscopic evidence for symmetry breaking, critical spin fluctuations, and three-dimensional magnetic ordering, revealing a strong coupling between lattice, charge, and spin degrees of freedom. Together, these results demonstrate the power of NMR to uncover correlated spin dynamics, dimensional crossover, and coupled structural and magnetic ordering in van der Waals quantum materials.

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Microscopic evidence for a Zhang-Rice triplet state in the van der Waals
antiferromagnet, NiPS_3

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Quantum-entangled states underpin many emergent phenomena in quantum materials, yet their direct experimental identification remains a challenge. NiPS_3 , a van der Waals antiferromagnet exhibiting a resolution-limited magnetic exciton in its ordered phase, has been proposed to host a many-body entangled Zhang-Rice triplet state. Here, using ^{33}S nuclear magnetic resonance (NMR) on ^{33}S -enriched NiPS_3 single crystals, we provide microscopic evidence for this charge-transfer state. The ^{33}S and ^{31}P Knight shifts as a function of temperature reveal a unified spin-triplet configuration arising from strong hybridization between a self-doped hole in the S 3p orbitals and a hole in Ni 3d orbitals. Furthermore, the ^{33}S nuclear spin-lattice relaxation rate exhibits a power-law divergence as it approaches the Neel temperature $T_N = 155$ K, indicating critical slowing down of collective charge fluctuations consistent with spin-nematic correlations. These results reveal a spin-charge intertwined ground state and establish the microscopic foundation for the exceptional coherence of the magnetic exciton in NiPS_3 .

Uniaxial tuning of La-based cuprates

Gediminas Simutis

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I will present our recent advances in using uniaxial pressure as a clean “surgical” tool to tune quantum phases while simultaneously obtaining microscopic insights via resonance and scattering experiments. In cuprates, multiple electronic and structural phases are situated in the energetic vicinity to one another and can coexist or compete in the materials, depending on the chemical or physical parameters. We combine uniaxial pressure with various probes to enhance or suppress the different phases and determine how they interact. I will in particular, discuss our findings on the importance of the structural properties to the interplay of charge and spin order with the eventual emergence of superconductivity. I will finish by presenting our ongoing activities at PSI to connect lab-based NMR studies to the accelerator-based experiments using muons, X-rays, and neutrons.



Strongly underdoped cuprates: new insights from NMR

Damjan Pelc

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Understanding the evolution from an antiferromagnetic insulator to an unconventional metal with high-temperature superconductivity remains one of the pivotal open questions in cuprate physics. In hole-doped cuprates, superconductivity appears at hole concentrations as low as 5%, but in most material families it coexists with a short-range ordered spin-glass state. While NMR can provide exquisite insight into the nature of the emergent metal, slow spin fluctuations associated with the spin glass have hampered NMR work for decades. In this talk, I will present our recent NMR results on two much-studied cuprate families, $(\text{La,Sr})_2\text{CuO}_4$ (LSCO) and $\text{HgBa}_2\text{CuO}_{4+x}$ (Hg1201), where we have overcome the longstanding difficulties at low doping levels to a large extent. In LSCO, we find evidence of nanoscale phase separation between metallic and insulating regions, with a connectivity change that coincides with the appearance of superconductivity. In turn, Hg1201 does not show any signatures of spin-glass correlations, which provides a unique opportunity to study the low-doping metallic state using NMR. We find good agreement between Knight shift and neutron scattering data, and recover the conventional Korringa relation between shift and spin-lattice relaxation at low temperatures. NMR thus provides key input for models of the metallic state at the edge of superconductivity in cuprates.

Commensurate SDW order with single spin-spinless-stripe in $\text{La}_3\text{Ni}_2\text{O}_7$

Hidekazu Mukuda

Osaka University, Japan

Remarkable high- T_c superconductivity (SC) with $T_c \sim 80$ K was reported for layered nickelate $\text{La}_3\text{Ni}_2\text{O}_7$ under high pressure. At ambient pressure, anomalies in the electronic states were reported below 150 K by many experimental studies, which have been attributed to the appearance of charge density wave (CDW) and/or spin density wave (SDW) orders. Among the possible candidates, the single spin-charge stripe order, the double spin stripe order, the double charge stripe order, and the double spin-charge stripe order have been proposed by various spectroscopic experiments. Nevertheless, a consensus has yet to be obtained. In order to reveal the spin and/or charge states in the density wave order phase, we performed ^{139}La -nuclear quadrupole resonance (NQR) measurements on $\text{La}_3\text{Ni}_2\text{O}_7$ at ambient pressure. There are two crystallographically-inequivalent La sites, the La(1) site between the NiO_2 planes and La(2) site at the out-of-plane blocking layers. The La(2)-NQR study in $\text{La}_3\text{Ni}_2\text{O}_7$ clearly distinguishes the La(2)a site of the ideal $\text{La}_3\text{Ni}_2\text{O}_7$ from the other La(2)b site in the different local environment. Below 150 K, nearly half of the intrinsic La(2)a sites are dominated by a finite internal field within the ab plane, while the other half is dominated by a zero internal field. This result can be consistently explained by a single spin-spinless-stripe order model with the reduced Ni magnetic moments that are parallel to the a -axis. These microscopic results provide further insight into understanding the relationship with the emergence of high- T_c states with low volume fraction at high pressure.



NMR of Kitaev-like quantum spin liquids in honeycomb magnets

Martin Klanjšek

Jožef Stefan Institute, Slovenia

In the last decade, honeycomb magnets based on transition metal ions have drawn significant attention in the physics community for two key reasons [1]. First, Alexei Kitaev showed in 2006 that a honeycomb lattice of spin-1/2 moments coupled via bond-dependent Ising interactions exhibits an exact quantum spin liquid ground state with two types of fractional elementary excitations: Majorana fermions (spinons) and visons (gauge-field excitations) [2]. Second, it was theoretically predicted that this model can be realized in compounds comprising edge-shared structural octahedra — such as IrO_6 , RuCl_6 , or CoO_6 — forming a honeycomb lattice [3,4]. I will present our nuclear magnetic resonance (NMR) experiments on two such candidate materials, $\alpha\text{-RuCl}_3$ and $\text{BaCo}_2(\text{AsO}_4)_2$. In RuCl_3 , we confirm Kitaev's prediction [2] that the spin-excitation gap exhibits a cubic magnetic field dependence at low fields, directly indicating the presence of Majorana fermions [5]. Our experiments reveal that the variation of this gap with the in-plane magnetic field direction in single crystals exhibits the expected six-fold rotational symmetry [6], with a total variation of only 15% relative to its mean value. This contrasts with thermodynamic measurements, where the gap drops to zero at the minima [7]. We attribute this difference to the distinct temperature regimes probed: below 4 K in thermodynamic measurements versus an intermediate range of 15–70 K in our NMR experiments. We interpret our results as a consequence of significant non-Kitaev interactions present in the compound. In $\text{BaCo}_2(\text{AsO}_4)_2$, we confirm the nearly linear magnetic-field dependence of the excitation gap of the magnetic continuum, as previously observed by THz spectroscopy [8] and inelastic neutron scattering [9]. Although this continuum is currently understood as a two-magnon continuum, our measurements reveal that its spectral intensity is far too high for such an assignment, indicating instead a spinon-based continuum [10]. At low temperatures in the field-polarized state, we observe a clear signature of low-frequency vison excitations. Studying their dynamics as a function of magnetic field, we find that they undergo a topological jamming crossover with increasing temperature [10].

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Probing Magnetism and Local Exchange Interactions in Infinite-Layer Nickelates via

¹³⁹La and ¹⁷O NMR

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Significant magnetic exchange interactions have been observed in hole-doped infinite-layer nickelates, RNiO₂ (R = La, Pr, Nd), which exhibit unconventional superconductivity. Although infinite-layer nickelates share the square-planar transition-metal–oxygen network and a $3d_{x^2-y^2}$ -dominated low-energy electronic structure with cuprates—suggesting conventional σ -bond-mediated superexchange as a plausible starting point—they also host additional low-energy states. Consequently, it remains unclear whether this conventional pathway alone can account for the observed magnetism and sizable exchange interactions. In this talk, I will introduce our recent ¹⁷O and ¹³⁹La nuclear magnetic resonance (NMR) measurements on LaNiO₂ and Sr-doped LaNiO₂. In both compounds, the ¹⁷O NMR spectra and nuclear spin-lattice relaxation rates ($1/T_1$) indicate short-range or inhomogeneous magnetic ordering at low temperatures, consistent with previous muon spin rotation results. In contrast, ¹³⁹La NMR results reveal a Sr-doping-induced spin-freezing behavior exclusively in Sr-doped LaNiO₂. This distinct magnetic response at different nuclear sites is attributed to the multiband electronic structure of infinite-layer nickelates. Crucially, our analysis of the ¹⁷O hyperfine coupling reveals that the Ni–Ni superexchange interaction, mediated by the σ bond between Ni- $d_{x^2-y^2}$ and O- p orbitals, is suppressed to approximately one-seventh of that in cuprates. This σ -bond contribution alone is insufficient to explain the total magnetic exchange interaction observed. First-principles and many-body cluster calculations indicate that an interstitial s orbital near the Fermi level, coupled with Ni- $d_{3z^2-r^2}$ and O- p orbitals, can generate an enhanced antiferromagnetic superexchange. This mechanism contrasts with cuprates, where magnetic interactions are predominantly governed by Cu- $d_{x^2-y^2}$ superexchange via oxygen. Our findings provide new insights into the distinct magnetic interactions in infinite-layer nickelates and their potential role in unconventional superconductivity.

Disentangling the critical fluctuations in heavy-fermion quantum criticality

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The ZrCuSiAs-structured rare-earth oxypnictides not only boosted a new wave of research boom on high- T_c superconductors, but also provided a novel playground for investigating strongly correlated electronic effects and quantum critical phenomena. Our previous works have manifested that CeNiAsO is an ideal candidate to explore the heavy-fermion properties of the 4f electrons. Here we revisit its pressure induced quantum critical point by ^{75}As measurements. The static and dynamic spin susceptibility at ambient pressure confirm that it enters an incommensurate AFM state below ~ 9 K, and then changes into a commensurate AFM phase below ~ 7 K. Under pressure, the incommensurate AFM disappears rapidly, and a quantum critical point is seen near 0.65 GPa between incommensurate AFM and paramagnetic phases. Quantum fluctuations from both spin and charge degrees of freedom are resolved around the QCP. Our results provide a rare example of disentangling the critical fluctuations in heavy-fermion quantum criticality.



NQR studies of microscopic structure, density waves in bilayer
and tri-layer nickelates

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The recent advances in bilayer nickelates $\text{La}_3\text{Ni}_2\text{O}_7$ have revealed fascinating high-temperature superconductivity (HTSC) under high-pressure conditions, offering a promising platform to explore unconventional superconducting mechanisms. In this talk, I will first discuss the discovery of bulk HTSC in Pr-doped $\text{La}_2\text{PrNi}_2\text{O}_7$, where Pr substitution effectively suppresses intergrowth phases, resulting in nearly pure bilayer structures. Superconducting onset temperature reaches 82.5 K at 16 GPa. Clear diamagnetic signals confirm the bulk nature of HTSC. I will also present microscopic evidence of charge and spin density wave (CDW/SDW) orders in $\text{La}_3\text{Ni}_2\text{O}_7$ and $\text{La}_4\text{Ni}_3\text{O}_{10}$, revealed through ^{139}La nuclear quadrupole resonance (NQR). At T_{DW} , $1/T_1T$ shows a clear peak in both samples. Below the density wave transition temperature, we observed distinct line splitting and magnetic broadening, indicating CDW order intertwined with SDW order. By integrating insights from high-pressure and NQR studies, these works provide a comprehensive understanding of the structural and electronic mechanisms underlying HTSC in bilayer and tri-layer nickelates, paving the way for future experimental and theoretical investigations.



Spin degrees of freedom in spin-triplet superconductor UTe_2

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Superconductivity in UTe_2 was discovered at the end of 2018 [1]. Although the superconducting (SC) transition temperature T_c was initially reported to be 1.6 K, it has recently increased to 2.1 K owing to improvements in crystal growth techniques [2,3]. UTe_2 shares many similarities with ferromagnetic (FM) superconductors, including Ising-type magnetic anisotropy and field-enhanced superconductivity. However, unlike FM superconductors, UTe_2 does not exhibit ferromagnetic order at low temperatures [4]. Shortly after its discovery, UTe_2 was considered the end member of the FM superconductor family, but subsequent studies revealed more complex magnetic fluctuations involving both FM and antiferromagnetic components [5,6]. Furthermore, distinct SC multiphases have been observed under strong magnetic fields applied along the b axis [7,8] and under hydrostatic pressure [9]. These unusual properties strongly suggest that UTe_2 is a spin-triplet superconductor. Spin-triplet superconductors possess internal spin degrees of freedom; however, how the spins of the triplet pairs respond to an external magnetic field remains unclear. To address this issue, we performed ^{125}Te Knight-shift and ac-susceptibility (χ_{ac}) measurements over a wide magnetic-field range, taking advantage of the strong hyperfine coupling between nuclear and electron spins. We found that the reduction in spin susceptibility below T_c is immediately recovered when a magnetic field is applied along the c axis ($H\parallel c$), accompanied by an enhancement of the upper critical field H_{c2} . Combined with the results for $H\parallel b$, these findings suggest a close relationship between the spin state of the triplet pairs and H_{c2} , as well as anisotropic pinning interactions acting on the superconducting spins. Such behavior, absent in conventional spin-singlet superconductors, may represent a hallmark of spin-triplet superconductivity [10]. We will also show the Knight-shift results in the pressure phase and discuss the relationship between high-field and pressure phases.

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Superconducting parity transition due to sublattice degrees of freedom
in the heavy fermion superconductor CeRh_2As_2

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Crystal symmetry is a fundamental determinant of quantum phenomena in solids. In superconductivity, global inversion symmetry has long served as the primary criterion for classifying the parity of the superconducting (SC) order parameter. In centrosymmetric systems, the SC state is strictly categorized into either even-parity spin-singlet or odd-parity spin-triplet states. However, recent theoretical advancements have introduced a new framework: locally noncentrosymmetric superconductors. In these systems, while global inversion symmetry is preserved in the crystal structure, the inversion center is absent at the specific atomic sites responsible for superconductivity. This local symmetry breaking introduces sublattice degrees of freedom, allowing for an exotic "odd-parity spin-singlet" state[1].

The heavy-fermion superconductor CeRh_2As_2 (SC transition temperature $T_{\text{SC}} \sim 0.3$ K) has emerged as a prime candidate for realizing this state[2]. Despite its low transition temperature, CeRh_2As_2 exhibits an anomalously high upper critical field H_{c2} exceeding 14 T for $H \parallel c$. Furthermore, a field-induced SC–SC phase transition occurs at around 4 T. This behavior is qualitatively consistent with theoretical predictions of a superconducting parity transition, where the system switches from a low-field even-parity state to a high-field odd-parity state (Fig. 1).

To elucidate the origin of these multiple SC phases, we performed ^{75}As -nuclear quadrupole resonance (NQR) and nuclear magnetic resonance (NMR) measurements on CeRh_2As_2 [3-5]. In the low-field SC phase, a reduction in the Knight shift was observed below T_{SC} . The Pauli limiting field estimated from this reduction is approximately 3.9 T, which is comparable to the SC–SC transition field, indicating that the low-field SC phase is a conventional even-parity spin-singlet state. In contrast, above 8 T, the Knight shift does not decrease even below T_{SC} , which is consistent with the behavior expected for the odd-parity spin-singlet state. Based on the NMR results, we will discuss the SC order parameters and the relationship between superconductivity and magnetism.

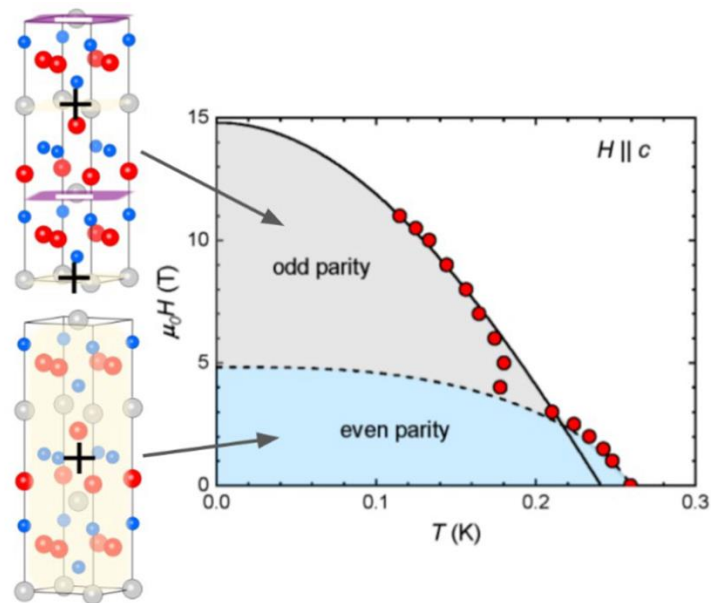


Figure 1: Phase diagram of CeRh_2As_2 (red circles)[2] and theoretically predicted superconducting states.

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⁷⁵As-NMR Study of Multiple Phases in the Spin-Triplet Superconductor K₂Cr₃As₃

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The recently discovered Cr-based superconductor K₂Cr₃As₃, with a superconducting transition temperature of ($T_c = 6.1$ K), has attracted considerable attention because of its unconventional superconducting properties [1]. K₂Cr₃As₃ crystallizes in a quasi-one-dimensional structure consisting of [Cr₃As₃]₂- tubes separated by K⁺ chains. The upper critical field significantly exceeds the Pauli paramagnetic limit [2]. Furthermore, ⁷⁵As nuclear magnetic resonance (NMR) and nuclear quadrupole resonance (NQR) measurements have revealed the development of ferromagnetic spin fluctuations in the normal state through the nuclear spin-lattice relaxation rate ($1/T_1$) and Knight shift [3,4]. In the superconducting state, $1/T_1$ exhibits no Hebel–Slichter coherence peak just below T_c and follows a T^5 temperature dependence. In addition, the spin susceptibility remains unchanged for magnetic fields perpendicular to the *c*-axis, whereas it is strongly suppressed to nearly zero for fields parallel to the *c*-axis. These results indicate that K₂Cr₃As₃ is a spin-triplet superconductor with point nodes in the superconducting gap. Moreover, for $B \parallel c$, the direction of the vector order parameter (the *d*-vector) characterizing the spin-triplet pairing is suggested to vary with magnetic field, implying the existence of multiple superconducting phases [5]. To clarify the multiple superconducting phase diagram of K₂Cr₃As₃, we have grown high-quality single crystals and carried out systematic ⁷⁵As-NMR measurements under magnetic fields applied parallel to the *c*-axis [6]. In the present study, we performed Knight shift and $1/T_1$ measurements under several magnetic fields to identify the superconducting order parameter in each phase. In this presentation, we will discuss the superconducting order parameters of K₂Cr₃As₃ inferred from these NMR measurements.



Spin-Fluctuation Anisotropy and Electronic Inhomogeneity in Ce- and Yb-Based Correlated-Electron Compounds: An NMR Perspective

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Heavy-fermion and Kondo-lattice compounds provide a rich platform for studying how anisotropic spin fluctuations and spatially inhomogeneous electronic states emerge from strong electron correlations. Nuclear magnetic resonance (NMR) and nuclear quadrupole resonance (NQR) are particularly powerful probes for this purpose, because they provide site-selective and direction-sensitive information on low-energy magnetic fluctuations and local electronic environments. In this talk, I will discuss NMR/NQR studies of several Ce- and Yb-based correlated-electron compounds. The main focus will be on Ce-115 systems, where chemical substitution reveals pronounced spin-fluctuation anisotropy, dopant-induced local magnetic textures, and electronic inhomogeneity in close connection with unconventional superconductivity and antiferromagnetism. I will also present related results on the triangular Kondo-lattice compound $\text{CePtAl}_4\text{Ge}_2$, where site-selective ^{27}Al NMR provides microscopic insight into anisotropic spin dynamics, and on the kagome Kondo-lattice compound YbV_6Sn_6 , where ^{51}V NMR reveals low-temperature magnetic correlations in the paramagnetic state. These examples highlight how local magnetic-resonance probes can clarify the interplay among lattice geometry, spin anisotropy, disorder, and strong correlations in f-electron materials.

Sb-NQR study of uniaxial-strain-tuned nodal superconductivity in the charge-ordered kagome metal CsV_3Sb_5

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The nature of the superconducting pairing symmetry in the kagome metal CsV_3Sb_5 and its relationship with the charge density wave (CDW) order are central unresolved issues. Here, we investigate the evolution of superconductivity in CsV_3Sb_5 under in-situ uniaxial pressure using ^{121}Sb nuclear quadrupole resonance (NQR). We find that tensile strain significantly enhances the superconducting transition temperature, T_c , while the CDW remains unchanged, demonstrating that superconductivity can be tuned independently of the bulk charge order. At a tensile strain of $\varepsilon = +0.90\%$, the nuclear spin-lattice relaxation rate reveals a remarkable double transition: an upper transition at $T_{c1} = 3.6$ K to a nodal gap state, and a lower one at $T_{c2} = 3.0$ K characterized by a nodeless gap. These results evidence degenerate superconducting states with different gap symmetry in the kagome metal at ambient pressure which split under strain. Our work demonstrates a high tunability of superconductivity by uniaxial pressure.



Unconventional superconductivity and loop-current order in kagome metal CsV_3Sb_5

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In this talk, we present low-temperature, high-pressure $^{121/123}\text{Sb}$ nuclear quadrupole resonance (NQR) and ^{51}V nuclear magnetic resonance (NMR) studies of the superconducting state and possible loop-current (LC) order in the kagome metal CsV_3Sb_5 . At ambient pressure, the spin-lattice relaxation rate $1/T_1$ shows a kink at approximately $0.4T_c$ and follows a T^3 dependence at low temperatures, suggesting two superconducting gaps with line nodes in the smaller gap. Above $P_c \approx 1.85$ GPa, where the CDW is completely suppressed, the Hebel-Slichter peak disappears and $1/T_1$ decreases faster than T^5 , indicating a fully opened gap. Meanwhile, the in-plane upper critical field H_{c2} exhibits a pronounced twofold angular dependence. We propose an $s + id$ pairing state above P_c to account for these observations [1]. We further observe a field-independent broadening of the ^{51}V NMR linewidth below $T^* \approx 45$ K, corresponding to an internal field of about 3.6 Oe. This provides microscopic evidence for a static LC state with orbital moments of approximately $0.002\text{--}0.01 \mu_B$ [2]. The LC order breaks the sixfold rotational symmetry down to C_2 , indicating intertwined TRSB and nematicity in the CDW phase. Our results reveal unconventional superconductivity and LC order in CsV_3Sb_5 , highlighting the intimate connection between symmetry breaking and superconductivity in kagome metals.

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Unconventional density-wave state in Ruddlesden–Popper nickelate $\text{La}_4\text{Ni}_3\text{O}_{10}$

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The recent discovery of superconductivity in Ruddlesden–Popper (RP) nickelates $\text{R}_{n+1}\text{Ni}_n\text{O}_{3n+1}$ (R = rare earth) under high pressure provides a new platform to understand the underlying physics of high-temperature superconductivity. Previous transport measurements suggest a notable correlation between pressure-induced high-temperature superconductivity and a density-wave (DW) state. Therefore, identifying the nature of the DW state is a prerequisite for decoding the superconducting mechanism in the new family of high-temperature superconductors. Here, we report a comprehensive investigation of the ambient-pressure DW transition in high-quality $\text{La}_4\text{Ni}_3\text{O}_{10}$ single crystals using ^{139}La ($I = 7/2$) nuclear magnetic resonance (NMR) and nuclear quadrupole resonance (NQR). Our findings reveal a two-stage evolution of the DW order. Below $T^* \approx 150$ K, a short-range charge order develops in the inner Ni–O layer, accompanied by a dramatic enhancement of spin fluctuations. This is followed by a DW transition at $T_{\text{DW}} \approx 133$ K, establishing fully developed charge and spin orders across all Ni–O planes. The layer-dependent behaviour highlights that the mechanism of DW transitions in $\text{La}_4\text{Ni}_3\text{O}_{10}$ may involve both the interlayer coupling and the electronic structure disparities between the inner and outer layers. These findings provide a new framework for understanding the complex DW state in RP nickelates and their potential role in high-temperature superconductivity.



Magnetic and electronic properties of the spin = 5/2 two-dimensional honeycomb system $\text{SrFeSnP}_3\text{O}_{12}$

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Two-dimensional honeycomb magnets with low coordination numbers provide an ideal framework for investigating the interplay between lattice geometry, reduced dimensionality, and magnetic interactions. While low-spin honeycomb systems have been extensively studied, their high-spin counterparts remain comparatively unexplored, despite their importance for understanding the classical limit of magnetism. In this work, we present a comprehensive investigation of a two-dimensional (2D) honeycomb lattice compound in which Fe^{3+} ions form a well-defined magnetic network. Magnetic susceptibility measurements reveal a transition at, signaling the onset of long-range antiferromagnetic order, which is further supported by heat capacity measurements. Nuclear magnetic resonance (NMR) measurements confirm the development of internal magnetic fields below, while the sub-linear temperature dependence of the spin-lattice relaxation rate above provides evidence for short-range spin correlations in the paramagnetic regime. Electron spin resonance measurements reveal a single isotropic resonance at high temperatures, indicating isotropic spin correlations within the 2D honeycomb lattice. Theoretical calculations of symmetric exchange interactions show that the nearest-neighbor in-plane exchange interaction is the dominant one and antiferromagnetic in nature. Our computed Wannier functions show that the interaction is mediated via the Fe-O-P-O-Fe superexchange pathway. Our calculation, including spin-orbit coupling, shows that the system has negligible magnetic anisotropy, suggesting an isotropic 2D Heisenberg spin model. Local probe measurements, such as electron spin resonance ESR and NMR, together with specific heat data, indicate the development of short-range antiferromagnetic correlations that persist well above the long-range ordering temperature. These results establish a model high-spin honeycomb magnet bridging the classical and quantum regimes of magnetism.

Recent Progress in NMR Studies of Rare-Earth Hexaborides REB_6

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Rare-earth hexaborides, REB_6 , exhibit a rich variety of physical properties originating from the multiple degrees of freedom of 4f electrons. Among them, SmB_6 has long been recognized as a Kondo insulator characterized by strong hybridization between 4f and conduction electrons. Previous nuclear magnetic resonance (NMR) measurements on the boron site (^{11}B -NMR) have captured the hybridization gap formation through the temperature-dependent nuclear spin-lattice relaxation rate and Knight shift, providing crucial insights into the electronic structure [1], including its response to magnetic fields [2] and pressure [3]. In contrast, SmB_6 has more recently attracted considerable attention as a promising candidate for a topological insulator driven by strong spin-orbit coupling, with a particular focus on the contribution of surface transport. CeB_6 is a prototypical material exhibiting antiferroquadrupolar (AFQ) order. In the finite-field region of the AFQ phase, ^{11}B -NMR measurements have played a crucial role in identifying the ordered structure (Oxy-type AFQ) through the detection of field-induced magnetic dipole and octupole moments [4,5]. On the other hand, experimental evidence in the zero-field region remains limited. Recent ultra-low-frequency ^{11}B nuclear quadrupole resonance (NQR) measurements do not show the expected splitting of the boron sites for the Oxy-type structure [6], suggesting a possible discrepancy between the ordered states at zero and finite magnetic fields. To address these emerging challenges in REB_6 , it is essential to develop new methodologies and expand the experimental regime of NMR. Here, we present and discuss our recent findings: surface-sensitive NMR studies on SmB_6 and extremely low-field NMR investigations on CeB_6 approaching the zero-field limit.

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Anisotropy and Spin Dynamics in Centrosymmetric Skyrmion Hosts

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Skyrmions are intriguing spin textures that are localized and unusually robust against perturbations due to their non-trivial vortex-like topology [1]. While they are typically stabilized by antisymmetric interactions in bulk materials without inversion symmetry, centrosymmetric skyrmion hosts have also been discovered in recent years. In these systems, both the skyrmion stabilization mechanisms and the parent zero-field magnetic ground states remain controversial. In our recent studies of centrosymmetric skyrmion hosts Gd_2PdSi_3 and GdRu_2Si_2 [2–4], we investigate their topological properties, spin dynamics, and the role of anisotropy and local inversion symmetry breaking around individual Gd–Gd bonds in stabilizing non-trivial magnetic phases. We study these effects in both their ground-state and skyrmion magnetic phases, employing muon spectroscopy (μSR), resonant X-ray scattering (REXS), magnetometry, and ab initio DFT calculations.

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Unveiling single-layer-like electronic correlations in bulk 1T-TaS₂

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Layered van der Waals materials offer a versatile platform for exploring emergent quantum phenomena because their electronic properties can be controlled not only by composition and lattice symmetry, but also by interlayer stacking. This stacking degree of freedom is especially important in correlated materials, where small changes in orbital overlap, dimensionality, and charge distribution can qualitatively reshape the electronic ground state. Understanding how interlayer stacking influences electronic correlations is therefore a central issue for both bulk layered compounds and artificially engineered two-dimensional heterostructures. The transition-metal dichalcogenide 1T-TaS₂ provides a particularly compelling example of this physics. Its low-temperature commensurate charge-density-wave (CDW) phase forms Star-of-David clusters on a triangular superlattice, making it a long-standing candidate for Mott physics and quantum spin liquid. However, in bulk 1T-TaS₂, the intrinsic intralayer correlated state is strongly intertwined with interlayer stacking and dimerization, making it difficult to distinguish purely two-dimensional electronic correlations from three-dimensional stacking effects. Here, by combining ³³S NMR with DFT calculations, we show that the ³³S quadrupolar interaction provides a sensitive local probe of the stacking environment. By comparing experimental spectra with simulations, we identify distinct microscopic stacking configurations in the commensurate CDW phase. More importantly, our results reveal that stacking is not merely a structural detail, but a decisive control parameter for electronic correlations. In the commensurate CDW, the spin dynamics indicate an insulating state governed by interlayer coupling. Upon warming into the nearly commensurate phase, interlayer coupling is suppressed while the intralayer Star-of-David charge motif is preserved. This dimensional decoupling reveals a strongly correlated regime: the spin-lattice relaxation rate increases dramatically by nearly two orders of magnitude, whereas the Knight shift changes only modestly. These results demonstrate that suppressing interlayer dimerization in bulk 1T-TaS₂ exposes single-layer-like electronic correlations, establishing interlayer stacking as a critical control parameter for correlated physics in layered quantum materials.

Magnetic clusters in the paramagnetic phase of a high-temperature ferromagnetic
metal-organic framework

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Owing to their exceptional chemical and electronic tunability, metal-organic frameworks can be designed to develop magnetic ground states - however, the typically weak exchange interactions mediated by the diamagnetic organic ligands result in ordering temperatures confined to the cryogenic limit. The itinerant magnetic ground state realized in the chromium-based framework $\text{Cr}(\text{tri})_2(\text{CF}_3\text{SO}_3)_{0.33}$ (Htri, 1H-1,2,3-triazole) is a remarkable exception to this trend, showing a robust ferromagnetic behavior almost at ambient conditions. In this contribution, I will discuss our recent results of dc SQUID magnetometry, ^1H nuclear magnetic resonance, and ferromagnetic resonance [1] as well as ^{53}Cr zero-field nuclear magnetic resonance [2] about the magnetic state realized in this material and highlight several thermally-activated relaxation mechanisms for the nuclear magnetization. I will report the development within the paramagnetic regime of mesoscopic magnetic correlated clusters whose slow dynamics in the MHz range are tracked by the nuclear moments, in agreement with the highly unconventional nature of the magnetic transition detected by dc SQUID magnetometry. I will discuss the similarity between the clustered phase in the paramagnetic phase and the magnetoelectronic phase segregation leading to colossal magnetoresistance in manganites and cobaltites. These results demonstrate that high-temperature magnetic metal-organic frameworks can serve as a versatile platform for exploring correlated electron phenomena in low-density, chemically tunable materials.

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Detection of Dirac/Weyl Fermions via electron-states resolved NMR crystallography

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The interest in the role of topology in condensed matter physics has been significantly increased over the last decade, with topological insulators and Dirac/Weyl semimetals being the most relevant systems featuring non-trivial topology. The state-of-the-art method to detect topological electron energy bands is Angle Resolved Photoemission Spectroscopy. However, despite its great effectiveness, there is a particular shortage in monitoring and manipulating Dirac and Weyl fermions, which appear as low energy quasiparticle excitations. Herein, we show that by applying broadband high-resolution solid-state Nuclear Magnetic Resonance (NMR) methods under Magic-Angle-Spinning and static conditions on microcrystalline WTe_2 [1] (type-II Weyl semimetal) Bi_2Te_3 nanoplatelets [2] (topological insulator) and microcrystalline SnSb_2Te_4 [3] (topological insulator), it is possible to routinely resolve complex ssNMR patterns into individual NMR resonances and monitor their relaxation properties. With the aid of DFT calculations of the k-resolved density of states and Knight shifts those resonances are then assigned to the Dirac/Weyl electron states via the origin of their electron-nuclear hyperfine coupling. Electron-states resolved NMR crystallography is thus enabling the detection of Dirac and Weyl Fermions.

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Anisotropic Exchange Coupling in the Magnetic Topological Semimetal α -EuP₃

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The discovery of semimetals with unique band structure has opened the possibility for external control of band topology. In semiconducting black phosphorus, pressure induces a transition from the semiconducting to the semimetallic states where Dirac Fermions are generated [1]. In its related magnetic material α -EuP₃, in which the magnetic element Eu is intercalated between the two-dimensional layers of black phosphorus, the control of the band topology by a magnetic field has been explored [2]. The exchange coupling between localized Eu-4f and P-3p electrons near the Fermi level in α -EuP₃ may modify the band structure, resulting in the emergence of Weyl or nodal-line semimetallic states, depending on the direction of an applied external magnetic field [2]. However, it remains experimentally unclear how the exchange coupling affects the band structure near the Fermi level. We have carried out ³¹P nuclear magnetic resonance (NMR) measurements to investigate the magnetic and electronic properties of α -EuP₃. The Knight shift (*K*) follows a Curie–Weiss law above 50 K with positive Weiss temperatures, indicating predominantly ferromagnetic correlations among Eu 4f moments. Despite nearly isotropic bulk susceptibility, *K* exhibits pronounced anisotropy, suggesting strongly anisotropic hyperfine coupling at the P sites. By evaluating the dipolar contribution arising from Eu 4f moments, we extract the transferred hyperfine component associated with the exchange coupling between Eu 4f and P 3p orbitals. The details of the anisotropic exchange coupling and its implications for the electronic structure will be discussed in the presentation.

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NMR Evidence of Flat-Band Destructive Interference in a Kagome Lattice

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Flat bands in kagome lattices arise from destructive quantum interference of electronic wavefunctions, but direct local evidence remains scarce. Here we report NMR measurements on the kagome material CoSn. By analyzing the hyperfine coupling constants of distinct d-orbital electrons, we identify site-dependent anomalies that directly signal the suppressed coherence characteristic of flat-band interference. In addition, we observe both in-plane ferromagnetic and out-of-plane antiferromagnetic fluctuations, which are closely linked to the flat bands. The interference pattern, together with the coexisting magnetic fluctuations, reveals a correlated state where flat-band physics and spin interactions are intricately intertwined.



Bogoliubov sum rule and the Knight-shift ellipsoid in spin-locked superconductors

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We establish an exact Bogoliubov sum rule for any Hermitian single-particle operator O : at each momentum, its particle-hole and particle-particle matrixelement weights sum to the single-particle trace $\text{Tr}_s(O^2)$. The result follows solely from Hilbert–Schmidt-norm invariance under a canonical Bogoliubov transformation and contains neither excitation-energy denominators nor occupations; physical response identities therefore require additional assumptions. At zero field, a fully gapped helicity-diagonal state with both helicity sheets present and a spin-orbit splitting asymptotically larger than the gap obeys $\chi_{\mu\nu}(0)/\chi_N = \delta_{\mu\nu} - \Pi_{\mu\nu} + o(1)$, where χ_N is the normal-state Pauli susceptibility and $\Pi = \langle \hat{\mathbf{n}}_{\mathbf{k}} \hat{\mathbf{n}}_{\mathbf{k}} \rangle_{\text{FS}}$ is the Fermi-surface average of the unit spin-locking texture. The eigenvalues of Π form a simplex, while the normalized spin Knight-shift tensor defines an ellipsoid whose semi-axes are the residual principal responses. Full cubic invariance of both the superconducting state and locking texture fixes $\Pi = 1/3$ and hence $\chi(0)/\chi_N = 2/3 + o(1)$; cubic crystal symmetry alone does not. For zero-field s-wave pairing in the reference-Fermi-surface regime, we obtain the exact closed-form kernel, $F_s(\lambda) = 1 - \text{asinh } \lambda / [\lambda \sqrt{1 + \lambda^2}]$ valid for arbitrary $\lambda = |\mathbf{g}|/\Delta$. In a finite Zeeman field, the zero-field helicity reduction generally fails, so the equilibrium magnetization and differential response require a self-consistent BdG calculation rather than a field-dependent locking-tensor substitution. Applied to the ^{75}As data on $\text{K}_2\text{Cr}_3\text{As}_3$, the framework identifies a field-dependent axial suppression pattern at 8–16 T. Both its placement near the $\hat{c}$ -axis vertex and the resulting tension with a specified decoupled-pocket spinorbit-texture baseline require an additional fixed-tensor $T \rightarrow 0$ and zero-field extrapolation; no unique microscopic pairing state follows.

Mapping the local spin dynamics of disordered materials using inverse Laplace transform $1/T_1$ analysis

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Analogous to how the NMR lineshape reflects the distribution of local spin susceptibility from various environments throughout the sample, the nuclear magnetization $M(t)$ measured during spin-lattice relaxation can reveal the spatial distribution of $1/T_1$. This $1/T_1$ distribution, represented as the probability density function $P(1/T_1)$, can be calculated from the inverse Laplace transform (ILT) of $M(t)$. To deal with the nontrivial $P(1/T_1)$ typical in disordered systems, we developed a program for directly computing $P(1/T_1)$ from measured $M(t)$ data, and employ regularization procedures to limit the instability of numerically inverting data with finite noise [1]. In this talk, we showcase our use of ILT $1/T_1$ analysis in our investigations on several materials exhibiting spatially inhomogeneous spin dynamics [2-4]. We demonstrate that ILT is a useful tool in NMR studies of correlated electron systems, and is more robust compared to traditional $1/T_1$ analysis methods (e.g. fitting $M(t)$ to a specific function), as it preserves the information contained in $M(t)$, avoids making strong assumptions about the form of $P(1/T_1)$, and can be extended to generate 2-dimensional data which reveal correlations between $1/T_1$ and Knight shift.

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NMR and NQR study on the multipolar order in heavy fermion Superconductor

CeRh₂As₂

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In this talk, we will report our recent ⁷⁵As nuclear quadrupole NQR and NMR measurements on single-crystal CeRh₂As₂. At near-zero magnetic fields, we observed that the ⁷⁵As(1) NQR frequency ν_Q increases linearly with temperature without any line broadening below the multipolar order transition temperature T_0 . Below the superconducting temperature T_c , we further observe the continuous evolution of the NQR frequency as well as pronounced line broadening at both As lattice sites. When the multipolar order is suppressed under high magnetic fields, the NQR frequency becomes temperature-independent and the line broadening vanishes. Our results indicate a strong correlation between the multipolar order and superconductivity in CeRh₂As₂, and suggest that the multipolar order drives additional symmetry breaking in the low-field superconducting state.

Microscopic Behavior in quasi-two-dimensional Altermagnets: Vanadium-Based Oxselenides

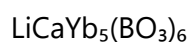
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Altermagnetism is a recently identified magnetic phase characterized by spin-split electronic band structures in collinear antiferromagnets with zero net magnetization. Owing to their unconventional symmetry and transport properties, altermagnets are of significant interest for both fundamental research and potential applications. Quasi-two-dimensional vanadium-based oxselenides have been proposed to host a *d*-wave altermagnetic state. In this work, we report NMR and muon spin rotation (μ SR) measurements performed on single crystals of a vanadium-based oxselenide. Our results reveal a microscopic interplay between magnetic order and density-wave behavior over a broad temperature range from 5 to 495 K. Zero-field μ SR measurements indicate the emergence of an incommensurate spin-density-wave (SDW) state below 110 K. Furthermore, we observe strong internal magnetic fields at the muon stopping sites, oriented along the crystallographic *c*-axis.



Low-temperature magnetism and spin dynamics in the triangular-lattice compound



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We report magnetization, heat-capacity, and ^7Li NMR investigations of the Yb^{3+} -based triangular-lattice compound $\text{LiCaYb}_5(\text{BO}_3)_6$. Rietveld refinement confirms a hexagonal $P6_322$ structure with partial Ca/Yb antisite disorder and fractional Li occupancy. Magnetic susceptibility reveals a well-isolated effective $J_{\text{eff}} = 1/2$ Kramers doublet with weak antiferromagnetic interactions. Heat-capacity measurements show short-range magnetic correlations below ~ 5 K and a weak anomaly near 0.43 K. ^7Li NMR spectra broaden strongly on cooling, indicating distributed internal magnetic fields and slow spin dynamics. The spin-lattice relaxation exhibits two relaxation components, consistent with disorder-induced local magnetic inhomogeneity. These results establish $\text{LiCaYb}_5(\text{BO}_3)_6$ as a frustrated Yb-based magnet where geometric frustration and structural disorder strongly influence the low-temperature magnetic state.

Magnetic field-induced TLL and BEC phases in an organic $S = 1$ Haldane chain

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Quantum fluctuations determine the ground state properties of low-dimensional quantum magnets - making them a compelling area of research. An $S=1$ Haldane chain is a one-dimensional (1D) quantum magnet where strong fluctuations result in quantum disordered singlet ground state with a gapped excitation spectrum. The gap magnitude is primarily set by the dominant intrachain interaction (J_{1D}). An applied magnetic field closes the gap at B_{c1} and drives the system into a gapless Tomonaga-Luttinger liquid (TLL) regime, followed by, at lower temperatures, a Bose-Einstein condensate (BEC) ground state, persisting up to $B_{c2} \sim 4J_{1D}/g\mu_B$. Almost all previously studied experimental realizations of such systems were based on transition-metal complexes which typically suffer from intrinsic anisotropies or large J_{1D} values, limiting the access to the full theoretical phase diagram. We report a comprehensive study of TLL and BEC phases [1] in the organic Haldane chain system m-NO₂PhBNO (BoNO). The remarkably low anisotropy manifests in an almost isotropic electron g tensor close to the free electron value (within 0.2%) [2]. The absence of anisotropy and a moderate J_{1D} result in achievable critical fields ($B_{c1} \sim 1$ T, $B_{c2} \sim 34$ T) which enables exploration of the complete B-T phase diagram. Through ¹H nuclear magnetic resonance, combined with magnetostriction measurements and theoretical analysis, we characterize the TLL properties, map the BEC phase boundary $T_c(B)$, determine the associated critical exponent ~ 0.66 at B_{c2} , and demonstrate universal quasiparticle scaling in the quantum-critical regime. These results provide full experimental validation of theoretical predictions [3,4] for field-induced phases in an $S=1$ Haldane chain, made over two decades ago.

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Evidence of Quantum Spin Liquid Ground State in Triangular Lattice Antiferromagnet

PrTa₇O₁₉

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A quantum spin liquid (QSL) is a novel quantum state in which spins are highly entangled, preventing long-range magnetic order even at zero temperature due to strong quantum fluctuations. Searching for QSL materials remains a central topic in modern condensed matter physics. Rare-earth (RE) based geometrically frustrated magnets offer a promising platform due to strong spin-orbit coupling and correlations in 4f electrons. The family RETa₇O₁₉, featuring a triangular lattice of RE³⁺ ions, has recently attracted attention as a candidate for hosting exotic quantum states. For instance, NdTa₇O₁₉ exhibits no magnetic order down to 40 mK with persistent spin dynamics, highlighting the potential of this family. However, the magnetic ground state of other members remains largely unexplored. We have successfully synthesized polycrystalline PrTa₇O₁₉. Specific heat measurements reveal the absence of magnetic order and spin freezing down to 0.4 K. Notably, the specific heat coefficient C/T displays an unusual field-dependent behavior, suggesting an exotic magnetic ground state distinct from simple paramagnetism. To further investigate the low-temperature spin dynamics and clarify the nature of this ground state, we also performed muon spin relaxation (μ SR) measurements on PrTa₇O₁₉.

Microscopic Evidence of Spin Supersolid State in the Triangular-Lattice Antiferromagnet

$\text{Na}_2\text{BaCo}(\text{PO}_4)_2$

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In a highly promising spin supersolid candidate, the triangular-lattice antiferromagnet $\text{Na}_2\text{BaCo}(\text{PO}_4)_2$ (NBCP), a zero-field muon spin relaxation (ZF- μ SR) study is reported. An enhancement of the muon relaxation rate is observed near the thermodynamically determined Berezinskii-Kosterlitz-Thouless (BKT) transition temperature ($T_N \approx 0.15$ K), attributed to the critical slowing down of spin fluctuations at the BKT transition. At ultra-low temperatures, the muon relaxation rate saturates at a large value without static spectral features, providing an evidence for persistent low-energy spin dynamics, supporting its identification as a spin supersolid candidate when considered together with thermodynamic, neutron, and NMR results.



Muon spin rotation and relaxation study on noncentrosymmetric superconductors

RhGe₄ and IrGe₄

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The noncentrosymmetric (NCS) superconductors, theoretically considered to be a platform to host unconventional superconductivity, have attracted considerable research attention. Due to the absence of inversion symmetry, antisymmetric spin-orbital coupling (ASOC) arises in these materials, which allows a superconducting ground state that is an admixture of spin-singlet and spin-triplet pairing state. As a result, the nontrivial structure may lead to a range of novel properties, including unconventional superconducting pairing state, topological superconductivity, and time-reversal symmetry breaking (TRSB) in superconducting state. Although the existence of TRSB has been confirmed in many NCS superconductors, the origin of it remains unknown. One of the key challenges in the study of NCS superconductors is to understand the correlation between the breaking of inversion symmetry and the potential TRSB. Recently, new type-II NCS superconductors RhGe₄ and IrGe₄ have been successfully synthesized under high pressure at ShanghaiTech University. The superconducting critical temperature of RhGe₄ and IrGe₄ are 2.6 K and 1.1 K, respectively. These two compounds crystallize in the NCS structure with the space group P3121 (No.152). Systematic characterization of these compounds has already been published, while reliable research on superconducting gap symmetry is still lacking. Muon spin rotation and relaxation (μ SR) experiments are performed on the polycrystalline samples. The increases of zero-field (ZF) muon relaxation rate of two samples are too small to independently determine whether TRS break in the superconducting states. Further research is needed to study the potential TRSB. Transverse-field (TF) μ SR measurements are carried out to investigate the superconducting gap symmetry of two superconductors. The superfluid density obtained by muon relaxation rate tend to support the conventional *s* wave pairing symmetry. However, *s+p* model exhibits better goodness of fits to the electronic heat capacity of IrGe₄ (submitted). In conclusion, TRSB is not observed in these two superconductors. The superconducting gap symmetry of these two compounds remains controversial.

Muon spin relaxation study of a multiband superconductor La_3In

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We report a muon spin rotation and relaxation (μSR) study of the superconducting properties of La_3In , complemented by low-temperature specific-heat measurements. Zero-field μSR experiments reveal an additional relaxation below the superconducting transition temperature, suggesting the possible appearance of spontaneous internal magnetic fields in the superconducting state. This observation may indicate time-reversal symmetry breaking. Transverse-field μSR measurements were performed to investigate the temperature dependence of the magnetic penetration depth and the corresponding superfluid density. The experimental data cannot be fully described by a conventional single-gap model and are better accounted for by a multigap superconducting scenario, indicating the possible involvement of multiple electronic bands in the superconducting pairing. Low-temperature specific-heat measurements also show features that deviate from a simple single-gap description and provide additional support for multiband superconductivity. These results suggest that La_3In may host an unconventional superconducting state characterized by multiple superconducting gaps and possible time-reversal symmetry breaking.



Singular spin fluctuations in the strange-metal phase of $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$

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Cuprate superconductors host in their phase diagram a so-called strange metal regime at doping levels beyond the pseudogap phase. In this regime, the electrical resistivity is linear in temperature down to the lowest temperatures, in contrast with the quadratic dependence in conventional metals [1]. Although spin fluctuations are central to the physics of high- T_c cuprates, their relevance to strange-metal behavior in the overdoped regime remains unclear. [2] Here [3], we use high magnetic fields to suppress superconductivity and an NMR protocol tailored to electronic inhomogeneity to show that the low-energy limit of the dynamical spin susceptibility $\chi''(Q, \omega \rightarrow 0)$ at $x=0.25$ in $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$ increases continuously down to our lowest temperatures. This behavior is suggestive of quantum-critical fluctuations, a leading candidate mechanism for strange-metal transport, yet is observed well beyond the spin-stripe critical doping $x^*=0.19$ [4]. Our data [3] further reveal that the spin dynamics are spatially inhomogeneous, suggesting that nanoscale electronic inhomogeneity may underlie this apparent paradox. These observations provide new insight into the electronic state from which strange-metal behavior emerges.

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Colossal Infrared Third-Harmonic Anisotropy in a Two-Dimensional Charge-Transfer

Mott Insulator

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Strongly correlated two-dimensional materials offer a promising route toward compact nonlinear photonic devices, yet achieving large and spectrally tunable optical anisotropy remains a central challenge. Here, we investigate vanadium oxychloride (VOCl), a two-dimensional antiferromagnetic charge-transfer Mott insulator, as a platform for anisotropic nonlinear optics. Structural and electronic analyses identify VOCl as a correlated charge-transfer system with a nearly thickness-independent bandgap of ~ 2.0 eV, indicating extremely weak interlayer electronic coupling. Polarization-resolved nonlinear optical measurements reveal a strong third-harmonic generation (THG) response in exfoliated VOCl flakes. Because electric-dipole second-harmonic generation is symmetry forbidden in VOCl, the nonlinear optical behavior is dominated by third-order processes. The material exhibits a third-order susceptibility on the order of 10^{-19} m²/V² with minimal thickness dependence. More importantly, VOCl shows pronounced in-plane anisotropy, with photoluminescence and THG anisotropy ratios reaching 6.8 and 187, respectively. Across the infrared excitation range from 2028 to 1280 nm, the THG anisotropy increases from 2.6 to 187, corresponding to a 72-fold enhancement. First-principles analysis attributes this giant nonlinear anisotropy to the combined effects of correlated charge-transfer excitations and intrinsic in-plane symmetry breaking. These results establish VOCl as a compelling material for polarization-sensitive nanophotonic and optoelectronic applications, and more broadly highlight charge-transfer Mott insulators as an emergent materials class for nonlinear optical engineering.



NMR Evidence of Flat-Band Destructive Interference in a Kagome Lattice

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Flat bands in kagome lattices arise from destructive quantum interference of electronic wavefunctions, but direct local evidence remains scarce. Here we report NMR measurements on the kagome material CoSn. By analyzing the hyperfine coupling constants of distinct d-orbital electrons, we identify site-dependent anomalies that directly signal the suppressed coherence characteristic of flat-band interference. In addition, we observe both in-plane ferromagnetic and out-of-plane antiferromagnetic fluctuations, which are closely linked to the flat bands. The interference pattern, together with the coexisting magnetic fluctuations, reveals a correlated state where flat-band physics and spin interactions are intricately intertwined.

Disentangling the critical fluctuations in heavy-fermion quantum criticality

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The nature of quantum critical point (QCP) and its related emergent states pose fundamental but still not fully answered questions. The past decades have witnessed accumulating examples of unconventional QCPs in heavy-fermion metals. Though theoretical models predicted that these unconventional QCPs in these systems are beyond Landau's classic framework of an order parameter in that they include not only the well conceived spin but also fermionic (charge) degrees of freedom, yet straightforward experimental evidence for the latter from a local and microscopic perspective is still lacking. Here, we explore the pressure-tuned QCP in CeNi(As,P)O by employing ^{75}As and ^{31}P nuclear magnetic resonance as local probes and show that the theoretically anticipated local-itinerant transition line separating the regimes with small and large Fermi surfaces is well determined experimentally and found to terminate at the QCP. Proliferation of charge fluctuations approaching QCP is corroborated by spin-lattice relaxation measurements. Our results demonstrate the involvement and suggest the vital role of critical charge fluctuations in unconventional criticality that potentially bear ubiquitous consequences- e.g. strange-metal character and unconventional superconductivity- observed in heavy-fermion systems and many others.



^{39}La nuclear quadrupole resonance studies of pressurized $\text{La}_4\text{Ni}_3\text{O}_{10}$

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In the recently discovered superconducting Ruddlesden-Popper (RP) phase nickelates, density wave phase transitions appear to be crucial for the emergence of superconductivity. To explore the underlying mechanism and elucidate the origin of superconductivity in nickelates, we report ^{139}La nuclear quadrupole resonance (NQR) results on the $\text{La}_4\text{Ni}_3\text{O}_{10}$ compound under various pressures. At ambient pressure, two spin density wave (SDW) transitions are observed at distinct temperatures of 146 K and 139 K, corresponding to short-range and long-range order, respectively, concomitant with a charge density wave (CDW) transition. Upon applying a pressure of 2.3 GPa, the transition temperatures of the short-range and long-range orders decrease at different rates, with the long-range order transition being suppressed more significantly. Such intertwined SDW and CDW transitions in $\text{La}_4\text{Ni}_3\text{O}_{10}$ are markedly distinct from the separately occurring SDW and CDW transitions in $\text{La}_3\text{Ni}_2\text{O}_7$, which may account for its lower superconducting transition temperature. Our work reveals the evolution of the density-wave phase transition temperature with pressure in $\text{La}_4\text{Ni}_3\text{O}_{10}$ and provides experimental evidence for further clarifying the mechanism of superconductivity emergence in RP-phase nickelates.

Pressure-Driven Superconducting Re-entrance and Magnetic Fluctuations in $\text{Fe}_{1-x}\text{Cu}_x\text{Se}$: A ^{77}Se NMR Study

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Iron-based superconductor Fe-chalcogenides host a rich phase diagram where nematic electronic order, impurity-induced local moment, and superconductivity compete with each other. At ambient pressure, Cu substitution on the Fe site introduces local magnetic moments near dopants and induces strong electronic localization, which simultaneously suppresses long-range nematic order and bulk superconductivity. Here we report systematic high-pressure ^{77}Se NMR and magnetization measurements on Cu-doped $\text{Fe}_{1-x}\text{Cu}_x\text{Se}$ single crystals. Upon hydrostatic pressure, the impurity-induced local moments are gradually quenched, the localized electronic states become delocalized, and superconductivity is successfully recovered. Both the Knight shift and spin-lattice relaxation rate $1/T_1T$ results demonstrate that antiferromagnetic (AFM) spin fluctuations, cooperatively enhanced by remnant nematic correlations, act as the dominant pairing glue for superconductivity. Our unified pressure-concentration phase diagram directly reveals the fundamental competition between impurity-driven localization and pressure-restored superconductivity, indicating that static long-range nematic order is not an indispensable prerequisite for superconducting pairing in FeSe-based systems.



Intertwined charge and spin density waves in trilayer nickelate $\text{La}_4\text{Ni}_3\text{O}_{10}$ revealed by ^{139}La NQR

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The recent discovery of high-temperature superconductivity in pressurized Ruddlesden-Popper nickelates, such as bilayer $\text{La}_3\text{Ni}_2\text{O}_7$ with T_c approaching 80 K and trilayer $\text{La}_4\text{Ni}_3\text{O}_{10}$, has highlighted the pivotal role of density wave orders in these systems. At ambient pressure, a density wave state emerges near the superconducting dome, yet whether this order is driven by charge or spin, and whether it is commensurate or incommensurate, remains controversial. To address this, we employed ^{139}La nuclear quadrupole resonance (NQR), a sensitive local probe of electric field gradients and internal magnetic fields, to investigate the density wave orders in trilayer $\text{La}_4\text{Ni}_3\text{O}_{10}$. In high-quality single-crystal and polycrystalline $\text{La}_4\text{Ni}_3\text{O}_{10}$, the ^{139}La NQR spectra exhibit abrupt broadening and frequency shifts below T_{DW} around 133 K, indicating a first-order-like density wave transition. The pronounced Lorentzian broadening without line splitting suggests that the charge density wave order is incommensurate, distinct from the commensurate charge density wave previously observed in bilayer $\text{La}_3\text{Ni}_2\text{O}_7$. Meanwhile, the spin-lattice relaxation rate $1/T_1T$ shows a strong enhancement at T_{DW} , signaling significant spin fluctuations associated with the spin density wave. By disentangling the quadrupole and magnetic contributions to the linewidth, we demonstrate that the first-order transition is likely driven by the charge density wave, while the spin density wave provides strong spin fluctuations. Furthermore, the residual $1/T_1T$ at low temperatures indicates that a substantial fraction of the Fermi surface remains ungapped in $\text{La}_4\text{Ni}_3\text{O}_{10}$, unlike the nearly fully gapped state in $\text{La}_3\text{Ni}_2\text{O}_7$. These findings reveal distinct density wave characters between trilayer and bilayer nickelates and establish a microscopic framework for understanding the interplay between density wave orders and superconductivity.

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Identifying short- and long-range charge density wave orders in kagome-lattice

ScV₆Sn₆ via NMR spectroscopy

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ScV₆Sn₆ is a V-based kagome-lattice material similar to the AV₃Sb₅ (A = Cs, Rb, K) family. Unlike AV₃Sb₅, ScV₆Sn₆ exhibits a three-dimensional charge density wave (CDW) order and yet no superconductivity transition has been observed at low temperature. In this work, we confirm the $\sqrt{3} \times \sqrt{3} \times 3$ CDW via NMR and detect NMR signatures of the $\sqrt{3} \times \sqrt{3} \times 2$ short-range order. Above the CDW transition temperature $T_{\text{CDW}} = 88$ K, full width at half maximum of the NMR spectra reveals sensitivity to short-range order. Below T_{CDW} , the NMR spectra corresponding to $[m = -7/2 \leftrightarrow -5/2]$ satellite transition of V split into two peaks, with an intensity ratio of 2:1. Detailed analyses show that a $\sqrt{3} \times \sqrt{3} \times 3$ charge density wave order in ScV₆Sn₆ is consistent with our experimental results.



The ^{121}Sb -NQR and ^{51}V -NMR study of charge-density-wave order in the kagome metal KV_3Sb_5 under pressure

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The kagome metal KV_3Sb_5 exhibits charge-density-wave (CDW) order, but its microscopic structure and high-pressure behavior remain unclear. Here, we report ^{121}Sb nuclear quadrupole resonance (NQR) measurements under hydrostatic pressures up to 2.45 GPa and ^{51}V nuclear magnetic resonance (NMR) measurements at ambient pressure and 8.9 T, performed on KV_3Sb_5 single crystals. The ^{121}Sb -NQR spectra are consistent with the $2\times 2\times 2$ inverse-star-of-David superlattice established in RbV_3Sb_5 . Above T_{CDW} , the Sb2 linewidth increases by more than an order of magnitude which far exceeds the broadening observed in CsV_3Sb_5 . We further observe that the temperature-dependent linewidth follows a Curie–Weiss law whose $\theta(P)$ vanishes at $P_c \approx 1.1$ GPa, defining a possible CDW quantum critical point.

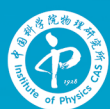
The growth of water in MOF303 investigated by NMR

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Metal organic frameworks(MOF) reveals various special properties due to its metal-site and organic-linker structure. MOF303 is based on Al^{3+} site and PZDC organic linker, it can absorb 30% mass ratio of water and remain stable due to its static net structure and hydrophilic bond. The NMR experiment was divided into two groups, the first ^1H NMR is conducted in different relative humidity from 11%RH to 27%RH, and water absorption time is 5 hours(make sure the sample is saturated) under $20^{\circ}C$; the second is in site ^1H NMR experiment, the absorption time ranges from 1s to 2 hours both in 14%RH and 20%RH at $20^{\circ}C$. The first was to study the transition of water in MOF303 in terms of different relative humidity, the second was about to study the growth of water cluster.





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