SUPERMAX
Toulouse, 14-18 October 2024

International Workshop on Superconductivity & Magnetism
in f-Electron Quantum Materials under Extreme Conditions

SCIENTIFIC PROGRAM AND ABSTRACTS

(update 16 Oct. 2024)

Co-chairs:

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Georg Knebel (Pheliqs, UGA, CEA, Grenoble, France)
Daniel Braithwaite (Pheliqs, UGA, CEA, Grenoble, France)
Ilya Sheikin (LNCMI, EMFL, CNRS, Grenoble, France)
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Cécile Laroche, Stéphane Lévignac, Tristan Thebault, Somesh Kalaiarasan (LNCMI, EMFL, CNRS, Toulouse, France)
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See also:

https://supermax.sciencesconf.org/

the European Magnetism Association

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PROGRAM AT A GLANCE

Monday, Tuesday, Wednesday & Friday sessions
San Subra conference room (Toulouse city center)

Thursday sessions & lunch:
Fermi conference room (Campus)

	Monday 14 Oct.	Tuesday 15 Oct.	Wednesday 16 Oct.	Thursday 17 Oct.	Friday 18 Oct.
Morning 1		UTe2 II – Chair K. Ishida	U compounds – Chair H. Suderow	Violin and Eu compounds – Chair T. Onimaru	UTe2 V – Chair M. Zhitomirsky
		9:00 - 9:30 **Jean-Pascal Brison**	9:00 - 9:30 **Stéphane Raymond**		9:00 - 9:30 **Youichi Yanase**
		9:30 - 10:00 **Alexander Eaton**	9:30 - 10:00 **Andrew Huxley**	9:20 - 9:50 **Luigi Paolasini**	9:30 - 10:00 **Satoshi Fujimoto**
		10:00 - 10:20 Sylvia Lewin	10:00 - 10:20 Somesh Kalaiarasan	9:50 - 10:20 **Motoi Kimata**	10:00 - 10:30 **Andriy Nevidomskyy**
		10:20 - 10:40 Nils Marquardt	10:20 - 10:40 Callum Stevens	10:20 - 10:40 Maria Victoria Ale Crivillero	10:30 - 10:50 Jushin Tei
BREAK		BREAK	BREAK	BREAK	BREAK
Morning 2		Skyrmions – Chair A. Huxley	CeRh2As2 – Chair S. Ran	UTe2 IV – G. Knebel	UTe2 VI – Chair D. Braithwaite
		11:10 - 11:40 **Koji Kaneko**	11:10 - 11:40 **Javier Landaeta**	11:10 - 11:40 **Yo Tokunaga**	11:20 - 11:50 **Sheng Ran**
		11:40 - 12:10 **Alexandre Pourret**	11:40 - 12:10 **Konstantin Semeniuk**	11:40 - 12:00 Thomas Halloran	11:50 - 12:20 **Koichi Izawa**
		12:10 - 12:30 Revaz Ramazashvili	12:10 - 12:40 **Daniel Agterberg**	12:00 - 12:20 Tristan Thebault	12:20 - 12:40 Zheyu Wu
LUNCH	12:00 - 13:50 Welcome 13:50 - 14:00 Opening	LUNCH	LUNCH	LUNCH	12:40 - 12:45 Closing
Afternoon 1	UTe2 I and URhGe – Chair D. Aoki	CeSb2 and URu2Si2 – Chair A. Severing	Yb and La – Chair S. Kambe	High fields & 2D – Chair I. Sheikin	
	14:00 - 14:30 **Jacques Flouquet**	14:20 - 14:50 **Atsushi Miyake**	14:30 - 15:00 **Takahiro Onimaru**	14:00 - 14:30 **Fabienne Duc**	
	14:30 - 15:00 **Kenji Ishida**	14:50 - 15:20 **Hisashi Kotegawa**	15:00 - 15:30 **Yoshiki Sato**	14:30 - 14:50 Fedor Balakirev	
	15:00 - 15:30 **Eric Bauer**	15:20 - 15:50 **Shinsaku Kambe**	BREAK	14:50 - 15:10 Mostafa Marzouk	
	15:30 - 15:50 Mike Zhitomirsky	15:50 - 16:10 Karel Prokes	17:30 - 22:00 **PENICHE SAMSARA** **CANAL DU MIDI** ***WINE & CHEESE*** ***& CONCERT***	BREAK	
BREAK	BREAK	BREAK		16:00 - 19:00 **POSTER SESSION** **+** **VISIT OF** **THE LNCMI** **PULSED FIELD** **FACILITY**	
Afternoon 2	U spectroscopy – Chair J.-P. Brison	UTe2 III – Chair Y. Tokunaga			
	16:20 - 16:50 **Gerard Lander**	16:40 - 17:10 **Michal Valiska**			
	16:50 - 17:20 **Andrea Severing**	17:10 - 17:40 **Toni Helm**			
	17:20 - 17:50 **Hermann Suderow**	17:40 - 18:00 Timothée Vasina			
	17:50 - 18:10 Evgenia Tereshina-Chitrova				

At the LNCMI (Campus)

1 Bd Monplaisir (Toulouse city center)

WIFI

San Subra conference room:

_Toulouse_wifi network available

Fermi conference room:

Eduroam network available

VENUE

Conference rooms:

- Sessions on Monday, Tuesday, Wednesday and Friday at the **San Subra conference room** in the City Center, 4 Rue San Subra, 31300 Toulouse

- Sessions on Thursday at the **Fermi conference room** at the University Campus, Bâtiment 3R4, 105 All. Théodore Despeyrous, 31400 Toulouse
    - From City Center, you can come with Metro B (stop at Faculté de Pharmacie then 5 minutes walk), or by bike along the Canal du Midi cycle path.

San Subra

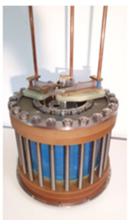

Fermi


Boat trip (with Wine & Cheese dinner):

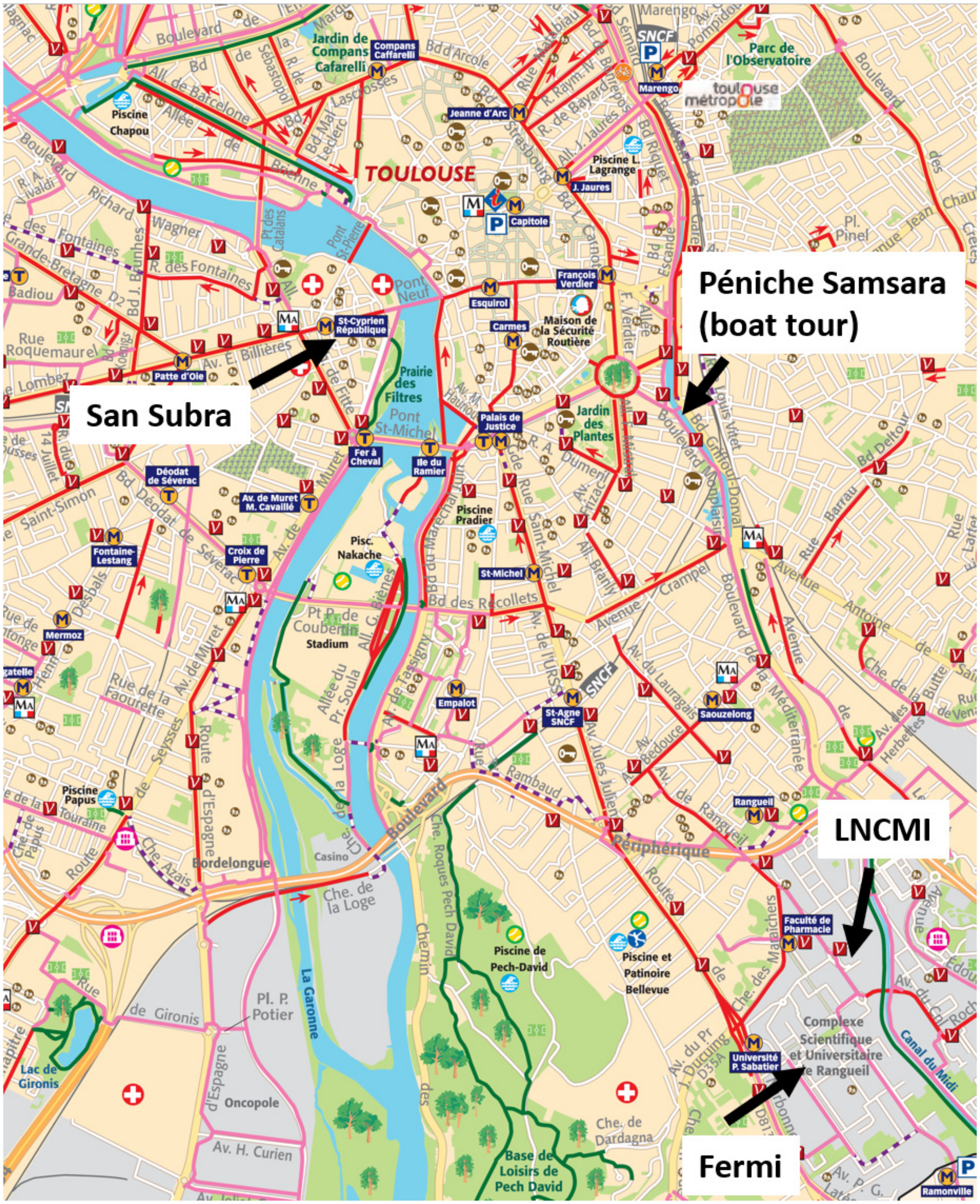
- Meeting point on Wednesday at 5:30 pm at the **Péniche Samsara** (Canal du Midi, City center): 1 Bd Monplaisir, 31400 Toulouse


Poster session and visit of the LNCMI pulsed-magnetic-field facility:

- Meeting point on Thursday at 4:00 pm at the **LNCMI** (University campus): 143 avenue de Rangueil, 31400 Toulouse

MAPS



Péniche Samsara
(boat tour)
San Subra
LNCMI
Fermi
TOULOUSE
Jardin de Compans Cafarelli
Parc de l'Observatoire
Piscine Chapou
Jeanne d'Arc
Capitole
Piscine L. Lagrange
J. Jaures
Marengo
François Verdier
Esquirol
Carmes
Maison de la Sécurité Routière
St-Cyprien République
Patte d'Oie
Prairie des Filtres
Pont St-Michel
Palais de Justice
Jardin des Plantes
Fer à Cheval
Ile du Ramier
Déodat de Séverac
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Faculté de Pharmacie
Complexe Scientifique et Universitaire de Rangueil
Université P. Sabatier
Lac de Gironis
Oncopole
Base de Loisirs de Pech David
La Garonne
Canal du Midi
Ramonville


San Subra
La Garonne
Hôpital de la Grave
Jardin Raymond VI
Hôtel Dieu
Pl. du Pr Combes
Pl. de l'Estrapade
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Place Olivier
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St-Nicolas
Centre Claudius Regaud
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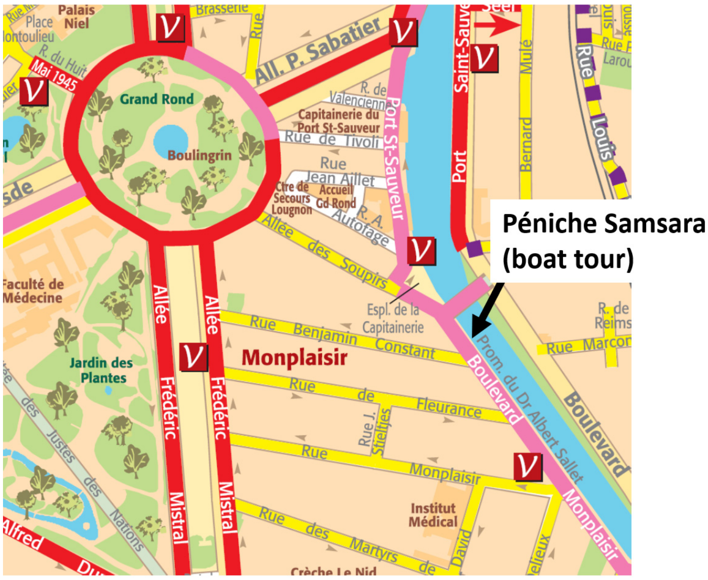
École Primaire Lespinasse


Péniche Samsara
(boat tour)
Grand Rond
Boulingrin
Jardin des Plantes
Faculté de Médecine
Monplaisir
All. P. Sabatier
Allée Frédéric Mistral
Rue Benjamin Constant
Rue de Fleurance
Rue Monplaisir
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Institut Médical
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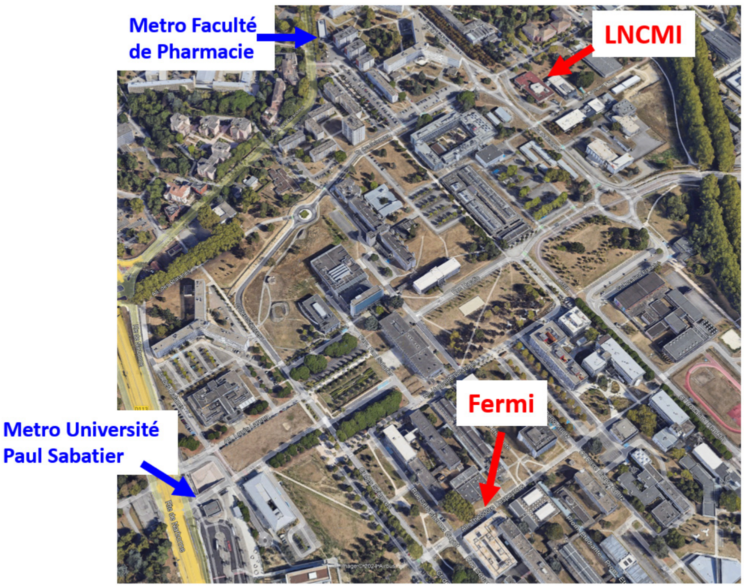
Metro Faculté
de Pharmacie
LNCMI
Fermi
Metro Université
Paul Sabatier

DETAILED PROGRAM

Monday 14 October

14:00 – 15:50 UTe2 I & URhGe – Chair D. Aoki

14:00 – 14:30 **Jacques Flouquet**, Novelty of UTe2 *(invited talk)*

14:30 – 15:00 **Kenji Ishida**, NMR measurements on superconducting multiphase in UTe2 *(invited talk)*

15:00 – 15:30 **Eric Bauer**, Recent Progress on Exploring the Normal and Superconducting States of UTe2 *(invited talk)*

15:30 – 15:50 **Mike Zhitomirsky,** Metamagnetism, tricriticality and field enhanced fluctuations in URhGe

16:20 – 18:10 U spectroscopy – Chair J.-P. Brison

16:20 – 16:50 **Gerard Lander**, Thin films of uranium systems: new materials, challenges, and opportunities *(invited talk)*

16:50 – 17:20 **Andrea Severing**, New spectroscopic insights into correlation effects and covalency of U 5f electrons in uranium intermetallic compounds *(invited talk)*

17:20 – 17:50 **Hermann Suderow**, Scanning tunneling microscopy at very low temperatures in heavy fermions *(invited talk)*

17:50 – 18:10 **Evgenia Tereshina-Chitrova**, Electronic structure evolution across the U-Te series from photoelectron spectroscopy

Tuesday 15 October

9:00 – 10:40 UTe2 II – Chair K. Ishida

9:00 – 9:30 **Jean-Pascal Brison**, Field and pressure control of the superconducting pairing mechanisms in UTe2 *(invited talk)*

9:30 – 10:00 **Alexander Eaton**, UTe2 in high magnetic fields *(invited talk)*

10:00 – 10:20 **Sylvia Lewin**, Field-induced superconductivity in UTe2

10:20 – 10:40 **Nils Marquardt**, Thermodynamic consequences of the themal expansion and magnetostriction in the field reinforced superconducting phase of UTe2

11:10 – 12:30 Skyrmions – Chair A. Huxley

11:10 – 11:40 **Koji Kaneko**, Magnetic skyrmion lattice in Eu-based f-electron magnets *(invited talk)*

11:40 – 12:10 **Alexandre Pourret**, Transport properties in the magnetic phases of non-centrosymmetric materials *(invited talk)*

12:10 – 12:30 **Revaz Ramazashvili**, Texture-induced spin-orbit coupling and skyrmion-electron bound states in a Néel antiferromagnet

14:20 – 16:10 CeSb2 and URu2Si2 – Chair A. Severing

14:20 – 14:50 **Atsushi Miyake**, Magnetization easy axis switch phenomena in CeSb2 *(invited talk)*

14:50 – 15:20 **Hisashi Kotegawa**, Nuclear quadrupole resonance study of pressure-induced superconductor CeSb2 *(invited talk)*

15:20 – 15:50 **Shinsaku Kambe**, NMR/NQR study of hidden ordering under uniaxial stress in URu2Si2 *(invited talk)*

15:50 – 16:10 **Karel Prokes**, Incommensurate field-induced phases in U(Ru0.98Rh0.02)2Si2 single crystal studied by neutron diffraction in pulsed fields up to 40 T

16:40 – 18:20 UTe2 III – Chair Y. Tokunaga

16:40 – 17:10 **Michal Valiska**, Lattice dynamics of UTe2 in high magnetic fields studied by ultrasound *(Invited talk)*

17:10 – 17:40 **Toni Helm**, Field-induced compensation of magnetic exchange as the origin of high-field superconductivity in UTe2 *(invited talk)*

17:40 – 18:00 **Timothée Vasina**, High-field and high-pressure superconducting phases in UTe2 probed by ac-calorimetry in pressure cells

Wednesday 16 October

9:00 – 10:40 U compounds – Chair H. Suderow

9:00 – 9:30 **Stéphane Raymond**, Magnetic structure of the Kagome metal UV_6Sn_6 *(invited talk)*

9:30 – 10:00 **Andrew Huxley**, Half quantum vortices. A robust non-fermi liquid state and unconventional superconductivity *(invited talk)*

10:00 – 10:20 **Somesh Kalaiarasan**, Electrical resistivity study on UGe_2 under intense magnetic field

10:20 – 10:40 **Callum Stevens**, Incommensurate charge density wave order and superconductivity in U_2Ti

11:10 – 12:40 CeRh2As2 – Chair S. Ran

11:10 – 11:40 **Javier Landaeta**, Weak Competition between Superconductivity and the Phase I Order in $CeRh_2As_2$ *(invited talk)*

11:40 – 12:10 **Konstantin Semeniuk**, Exposing quantum criticality and odd-parity superconductivity in $CeRh_2As_2$ with hydrostatic pressure *(invited talk)*

12:10 – 12:40 **Daniel Agterberg**, Superconductivity with strong spin-orbit coupling: application to $CeRh_2As_2$ *(invited talk)*

14:30 – 15:50 Yb and La – Chair S. Kambe

14:30 – 15:00 **Takahiro Onimaru**, Incommensurate modulation and magnetic anisotropy in an effective spin-1/2 zigzag chain of $YbCuS_2$ *(Invited talk)*

15:00 – 15:30 **Yoshiki Sato**, Large transverse thermoelectric conversion induced by the dimensionality of Fermi surface *(Invited talk)*

Thursday 17 October

9:20 – 10:40 Eu and La compounds – Chair T. Onimaru

9:20 – 9:50 **Luigi Paolasini**, The Paganini's violin "the Cannone": history, music and science *(invited talk)*

9:50 – 10:20 **Motoi Kimata**, Nonreciprocal transport in noncentrosymmetric antiferromagnets - probing spin texture and hidden symmetry breaking *(Invited talk)*

10:20 – 10:40 **Maria Victoria Ale Crivillero**, Exploring the Enigma of Colossal Magnetoresistance in new Eu-based compounds: Insights from macroscopic to atomic length scales

11:10 – 12:20 UTe2 IV – G. Knebel

11:10 – 11:40 **Yo Tokunaga**, NMR study of spin fluctuations and superconductivity in UTe2 *(invited talk)*

11:40 – 12:00 **Thomas Halloran**, Connection between f-electron correlations and magnetic excitation in UTe2 through inelastic neutron scattering

12:00 – 12:20 **Tristan Thebault**, Reinforcement of electronic correlations at the metamagnetic transition of UTe2 in a magnetic field in the (b-c) plane

14:00 – 15:10 High fields & 2D – Chair I. Sheikin

14:00 – 14:30 **Fabienne Duc**, Neutron Diffraction in Pulsed Magnetic Fields up to 40 T *(invited talk)*

14:30 – 14:50 **Fedor Balakirev**, Near-Room Temperature Superconductivity under Extreme Pressures and Intense Magnetic Fields

14:50 – 15:10 **Mostafa Marzouk**, Superconductivity and Ferromagnetism Coexistence in Two dimensional Electron Gases

16:00 – 19:00 Posters

P1 **Akihiro Minamide**, Phase diagram and novel vortex state in superconductors with sublattice degrees of freedom

P2 **Tetiana Haidamak**, High field study of UTe3

P3 **William Knafo**, Incommensurate antiferromagnetism in UTe2 under pressure

P4 **Georg Knebel**, Field-enhancement of superconductivity in UTe2 under magnetic field

P5 **Arno Hiess**, Current and future experimental possibilities for investigating actinide-based materials with neutrons

P6 **Ryuji Hakuno**, Magnetism and superconductivity in the two-sublattice periodic Anderson model for UTe2

P7	**Pablo Garcia Talavera**, Direct observation of a pair density wave in the high field phase of FeSe
P8	**Meike Pfeiffer**, Pressure-tuned quantum criticality in the locally non-centrosymmetric superconductor CeRh2As2
P9	**Liu Hao Tjeng**, Why different spectroscopies give seemingly different answers on U compounds
P10	**Jeremy Sourd**, Probing Lifshitz transitions in the quasi-1D heavy fermion compound YbNi4P2 with ultrasound
P11	**Kumar Sudhanshu**, Temperature-dependent neutron diffraction and magnetic studies on magnesium ferrite (MgFe2O4) powder prepared via sol-gel auto combustion method using DL-alanine fuel
P12	**Maxime Leroux**, Superconducting critical current measurements in pulsed magnetic field up to 60T
P13	**Daniel Braithwaite**, High pressure studies in pulsed magnetic field
P14	**Marc Nardone**, Cryogenic developments at the LNCMI-T

Friday 18 October

9:00 – 10:50 UTe2 V – Chair M. Zhitomirsky

9:00 – 9:30 **Youichi Yanase**, Theoretical studies of multiple superconducting phases in CeRh2As2 and UTe2 *(invited talk)*

9:30 – 10:00 **Satoshi Fujimoto**, Topology and multiple superconducting phases of UTe2 *(invited talk)*

10:00 – 10:30 **Andriy Nevidomskyy**, Towards uncovering the mystery of the high-field superconducting phase in UTe2 *(invited talk)*

10:30 – 10:50 **Jushin Tei**, Microscopic mechanism and pairing symmetries of multiple superconducting phases in UTe2

11:20 – 12:40 UTe2 VI – Chair D. Braithwaite

11:20 – 11:50 **Sheng Ran**, Revealing a 3D Fermi Surface and Electron-Hole Tunneling in UTe2 with Quantum Oscillations *(Invited talk)*

11:50 – 12:20 **Koichi Izawa**, Quasiparticle Heat Transport and Gap Structure of Ultraclean UTe2 *(invited talk)*

12:20 – 12:40 **Zheyu Wu**, Mapping the rich superconducting phase diagram of ultraclean UTe2

ABSTRACTS

Monday 14 October

14:00 – 15:50 UTe2 I & URhGe – Chair D. Aoki

14:00 – 14:30 Jacques Flouquet, Novelty of UTe2 *(invited talk)*

I will try to review why UTe2 is a striking case in the domain of strongly correlated systems ; my feeling on the present status of many publications . May be assuming I am a young researcher what I will try to do next : what is missing ? As introduction I will point out how Toulouse success to bring unique personalities such as Riquet , Fermat .....up to the Nobel winner Fert I was an student in Toulouse for two years in Lycée Fermat ; at this time we play football in Jacobin's convent.

14:30 – 15:00 Kenji Ishida, NMR measurements on superconducting multiphase in UTe2 *(invited talk)*

Superconductivity in UTe2 was discovered at the end of 2018[1]. Soon after the discovery, clear SC multiphase behavior was reported under strong magnetic field along the b axis and under hydro-static pressure. For H || b, Tc first decreases with increasing H and shows a minimum at around 16 T, then Tc increases up to 35 T[2]. The bulk SC properties in the high-field SC phase were recently confirmed by thermodynamic and AC measurements[3,4]. Under pressure (P), the Tc of UTe2 increases to about 3 K at 1.2 GPa. Below 1.6 GPa, the two jumps in the temperature (T) dependence of specific heat indicate the existence of at least two SC phases [2]: one exists at ambient pressure (SC1) and its Tc gradually decreases with applying P, and the other is an SC phase induced by P above 0.5 GPa (SC2), whose Tc has a maximum at 1.2 GPa. As a result, Tc of the SC1 is below Tc of the SC2 above 0.5 GPa, and thus this SC state is called SC3. Above 1.6 GPa, superconductivity suddenly disappears, and the antiferromagnetic state was observed[2]. To elucidate SC properties of the multiple SC phases as well as the high-quality single crystal with Tc = 2.1 K, nuclear magnetic resonance (NMR) measurements have been performed on 125Te-enriched UTe2 sample. Since nuclear spins interact with electron spins through strong hyperfine interactions, NMR enables to investigate the spin susceptibility in the SC state. In my presentation, I will show our NMR results in the multiple SC state[4, 5], and discuss possible SC order parameter based on the experimental results.

References

[1] S. Ran et al., Science 365, 684-687 (2019).

[2] D. Aoki et al., J. Phys. Condens. Matter 34, 243002 (2022).

[3] A. Rosuel et al., Phys. Rev. X 13, 0110022 (2023).

[4] K. Kinjo et al., Phys. Rev. B 107, L060502 (2023).

[5] K. Kinjo et al., Sci. Adv. 9, eadg2736 (2023).

15:00 – 15:30 **Eric Bauer**, Recent Progress on Exploring the Normal and Superconducting States of UTe2 *(invited talk)*

UTe2 has attracted recent interest due to its complex temperature-pressure phase diagram, with multiple superconducting phases in proximity to antiferromagnetism, and that it may host a topological, odd-parity superconducting state. We investigated high-purity single crystals by means of specific heat measurements under pressure, uniaxial strain measurements, and optical Kerr effect measurements to shed light on its superconductivity [1-4]. Our results on UTe2 indicate that a chiral, multi-component superconducting order parameter is unlikely in this material and place further constraints on the possible superconducting order parameters. We also investigated the normal state of UTe2 under pressure via X-ray absorption spectroscopy, X-ray diffraction, and nuclear magnetic resonance (NMR) measurements [1,5,6]. We found evidence for a mixed-valent state comprised of U4+ and U3+ configurations, wherein the U 5f electrons tend to localize above 1.5 GPa where antiferromagnetic order occurs. Te-125 NMR measurements under pressure reveal critical slowing down at the Te(1) site, which has a tetrahedral coordination of U atoms, just above the higher antiferromagnetically ordered phase at T_M1=11 K at 1.8 GPa; no critical slowing down is observed at the Te(2) site, which has a square planar arrangement of U atoms. One possibility is that the internal fields cancel each other at the Te(2) site, which may be understood if AFM magnetic order has a commensurate wavevector. Our X-ray diffraction measurements reveal that UTe2, which at ambient conditions has an orthorhombic (Immm) structure, transforms to a body-centered tetragonal (I4/mmm) structure at 5 GPa. This tetragonal high-pressure phase can be stabilized to ambient conditions to examine its properties. I will discuss these measurements and our recent progress towards understanding the properties of UTe2.

[1] S.M. Thomas et al. Science Advances 6, eabc8709 (2020);

[2] P.F.S. Rosa et al. Communications Materials 3, 33 (2022);

[3] C. Girod et al. Physical Review B 106, L121101 (2022);

[4] M. O. Ajeesh et al. Physical Review X 13, 041019 (2023);

[5] L.Q. Huston et al. Physical Review Materials 6, 114801 (2022);

[6] R. Yamamoto et al. (unpublished)

15:30 – 15:50 **Mike Zhitomirsky,** Metamagnetism, tricriticality and field enhanced fluctuations in URhGe

URhGe is a ferromagnetic heavy-fermion superconductor with distinct magnetic properties. Possessing an easy direction along the c axis, URhGe exhibits a first-order orientational transition in a transverse magnetic field H//b. A superconducting phase appears in the vicinity of this metamagnetic transition indicating enhanced magnetic fluctuations. We develop a theoretical description of the magnetic properties of URhGe by considering a spin model that includes competing anisotropies in the bc plane. The model is investigated analytically at zero temperature as well as at finite T using the Monte Carlo simulations. We obtain the H-T phase diagram and locate the tricritical point for H//b. We further explore the tricritical behavior and demonstrate that enhanced magnetic fluctuations persist down to low temperatures.

16:20 – 18:10 U spectroscopy – Chair J.-P. Brison

16:20 – 16:50 **Gerard Lander**, Thin films of uranium systems: new materials, challenges, and opportunities *(invited talk)*

Thin films of uranium systems: new materials, challenges, and opportunities G. H. Lander, Dept. of Physics, University of Bristol, Bristol UK Thin films present new properties of materials, as well as allowing solutions to older questions, especially if epitaxial samples can be produced. A review of this field, as related to uranium, has recently been published [1], and this talk will present some highlights from the work on thin U-based films at Bristol University. Studies or uranium metal, for example, show how the interaction between film and substrate can change the properties of the film, especially with respect to the onset of the charge-density wave and superconductivity. This interaction also allows the formation of epitaxial samples of U-Mo alloys in the bcc structure and, for the first time, close examination of the phonon spectra for such materials. Epitaxy samples have also been made of UO2 and UN, and of higher oxides and nitrides. The use of resonance X-ray scattering at the U M edges of some of these samples has shown new effects related to the aspherical charge density of the 5f states when they participate in the bonding. Many important applied questions can also be addressed with thin films. Examples include dissolution studies, phase relationships, the study of irradiated thin films, and the exploration of new phases. Epitaxial films of heavy fermion materials of UPd2Al3 and UNi2Al3 were first made in the 1990s [1] with an MBE technique, but the need to mix at least 3 elements makes the processes more complicated. This is certainly a growth area for the future, as is the investigation of spintronics, exchange-bias effects, and the use of multilayers with uranium. An overwhelming advantage of thin films is the very small quantities needed. Most of our samples contain only micrograms of U, so that most safety conditions are easily met. This is important in many respects, especially transport of samples, which is becoming increasingly difficult.

[1] R. Springell et al. Advances in Physics 71, 87-165 (2022)

16:50 – 17:20 **Andrea Severing**, New spectroscopic insights into correlation effects and covalency of U 5f electrons in uranium intermetallic compounds *(invited talk)*

The intriguing properties of U intermetallics arise from the intricate interplay of band formation and electron correlation effects of U 5f electrons. Describing their electronic structure is challenging, especially since atomic-like states have remained experimentally inaccessible. Ongoing disputes revolve around the existence of atomic-like states and, if present, determining which configuration U 5f3 or U 5f2 provides the Ansatz or starting point for describing low-energy properties. Furthermore, these correlated compounds exhibit strong intermediate valency, fuelling intense debates about the degree of itinerancy and actual filling of the 5f shell, thus necessitating new experimental tools. This presentation introduces two novel and complementary methods: (1) valence band resonant inelastic x-ray scattering (RIXS) using tender x-rays and (2) photon energy-dependent photoelectron spectroscopy (PES & HAXPES) in combination with DMFT calculations. Photon Energy-Dependent PES & HAXPES: Leveraging the photon energy dependence of photo-ionization cross-sections in PES and HAXPES, we disentangle contributions from different shells to the valence band. This information enables the material-specific tuning of the double-counting and other parameters in LDA+DMFT calculations and ensures a reliable and accurate description of the electronic structure of uranium in these intermetallic compounds, including a quantitative modelling of the often used U 4f core-level spectra. This approach provides the distribution of contributing U 5fn configurations and the mean 5f filling [1]. Valence Band RIXS: Using high-resolution RIXS at the U M-edges (3.5-3.7 keV), we observe low-energy excitations originating from atomic-like multiplet interactions [2,3]. The excellent signal-to-background ratio and the multiplet structure serve as a unique fingerprint for the U 5fn configuration involved, offering clear evidence of the presence of local correlation physics. This method unambiguously determines the dominating configuration. The presentation showcases contrasting examples from the diverse family of U intermetallics, spanning U-U distances from well above to well below the Hill limit. This exploration unveils surprises and offers solutions to new and long-standing problems in the field.

[1] A. Marino, A. Hariki et al., arXiv:2404.06266

[2] A. Marino et al. Phys. Rev. B, 108 (2023) 045142

[3] D. S. Christovam et al., arXiv:2402.03852

17:20 – 17:50 **Hermann Suderow**, Scanning tunneling microscopy at very low temperatures in heavy fermions *(invited talk)*

Local studies of the electronic density of states have been often focused on understanding oscillatory behavior due to scattering by defects, with techniques as quasiparticle interference. I will show that the non-oscillatory behavior, until now largely overlooked, is directly related to the local hybridization pattern and shows the emergence of correlated magnetism at zero temperature. I will also present new insight into the charge density modulation of UTe2 and advances in the construction of a new miniature microscope for very high magnetic fields.

17:50 – 18:10 **Evgenia Tereshina-Chitrova**, Electronic structure evolution across the U-Te series from photoelectron spectroscopy

Uranium tellurides exhibit phenomena ranging from magnetism to unconventional superconductivity. In this study, we conduct in-situ photoemission experiments on UxTey thin films. By comparing U-4f core-level XPS and valence band UPS spectra and contrasting them with DFT calculations and physical properties, we aim to elucidate electronic structure changes across various U-Te stoichiometries.

Tuesday 15 October

9:00 – 10:40 UTe2 II – Chair K. Ishida

9:00 – 9:30 **Jean-Pascal Brison**, Field and pressure control of the superconducting pairing mechanisms in UTe2 *(invited talk)*

Adrien Rosuel1, Christophe Marcenat1, Georg Knebel1, Thierry Klein2, Alexandre Pourret1, Albin Demuer3, Gabriel Seyfarth3, Gerard Lapertot1, Dai Aoki4, Daniel Braithwaite1, Jacques Flouquet1, M. Kimata4, K. Sudo4, A. Miyata5, Toni Helm5, Jean-Pascal Brison1

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UTe2, belongs to the rare class of superconductors presenting several different superconducting phases: this has been well established at finite pressures [1]. It was long suspected at zero pressure that for field along the hard b-axis, a field-induced transition to a new superconducting phase was responsible for the strong reinforcement of the upper critical field above 15T. Our thermodynamic measurements at ambient pressure up to 36T [2] show clear evidence for two different superconducting phases at finite fields along the hard b-axis, and we will discuss how this imply two different pairing mechanisms, a unique case among unconventional superconductors. We discuss these mechanisms for the two phases according to theoretical proposals for ambient and finite pressure phase diagrams, and propose a possible transition from spin-triplet to spin-singlet order parameters. Last, we will discuss the field re-entrant superconducting phase in the polarized regime above Hm. Hall effect measurements do show a distinctive feature in the angular range where the re-entrant superconducting phase emerges, namely it vanishes in the polarized normal state [3]. This allows to propose a first mechanism for the reentrant superconducting phase above Hm, related to the field reinforced phase along the b-axis [3].

[1] Braithwaite, D. et al., Communications Physics, 2, 147 (2019)

[2] Rosuel, Phys. Rev. X, 13, 011022 (2023)

[3] Helm, T. et al., Nature comm. 15, 27 (2024)

9:30 – 10:00 **Alexander Eaton**, UTe2 in high magnetic fields *(invited talk)*

The heavy fermion superconductor UTe2 hosts a diverse number of distinct superconducting states under various conditions of applied pressure and magnetic field. It appears very likely that some of these states are odd-parity in character, motivating their investigation both for possible future technological purposes as well as for the fundamental scientific interest in exploring such a rare state of quantum matter. This talk will review our recent measurements of UTe2 in high magnetic fields. Access to pristine quality samples has enabled us to map the Fermi surface of

this material - an important first step on the path to building an accurate microscopic description of the exotic superconductivity. Furthermore, in our recent pulsed field measurements to 80 T we have uncovered a quantum phase transition at very high magnetic field strengths, that appears to underpin the formation of extremely magnetic field resilient superconductivity in UTe2.

10:00 – 10:20 **Sylvia Lewin**, Field-induced superconductivity in UTe2

In addition to the rich physics of its zero-field superconducting state, UTe2 presents a variety of unusual behaviors in applied magnetic fields. This talk will focus on the high-field superconducting state of UTe2 that appears only for fields beyond a metamagnetic transition. This phase was first observed for fields in the bc plane, but we have now discovered that it extends well outside the bc plane and emerges with magnetic fields tilted a moderate amount from the crystalline b axis. The experimental evidence for this conclusion will be discussed, as will its implications for the superconducting order parameter. Phenomenological modeling shows that a non-unitary spin triplet state is consistent with the observed field-angle-dependence of the upper critical field of this superconducting phase.

10:20 – 10:40 **Nils Marquardt**, Thermodynamic consequences of the themal expansion and magnetostriction in the field reinforced superconducting phase of UTe2

Magnetostriction and thermal expansion are very powerful and sensitive thermodynamic bulk measurement techniques, in particular for the exploring superconducting phases. From thermodynamics, the latter is sensitive to entropy changes occurring under pressure and thermal expansion necessary to calculate in combination with the specific heat the Grüneisen parameter. On the other hand, magnetostriction is related to magnetization changes under pressure and opens another possibility to study the irreversible magnetization due to the vortex lattice pinning in type II superconductors. Thus, both are ideal techniques to explore unconventional superconductivity in heavy fermion systems.

Here we report magnetostriction and thermal expansion studies performed in the superconducting state of the novel heavy fermion superconductor UTe2 [1], up to 30 T for magnetic fields along the b-axis. For magnetic fields along this crystallographic axis UTe2 shows field reinforced superconductivity up to a metamagnetic transition at 35 T. We observe different irreversibility lines between the low-field and the high-field reinforced superconducting phase. Together with a detailed study of the specific heat, this is leading to the assumption of two different pairing mechanisms stabilizing superconductivity along the b-axis in UTe2 [2]. Furthermore, we present new high accuracy measurements of the linear thermal expansion along each crystallographic axis, while exploring these two superconducting phases of UTe2 and confirm that, in agreement with the specific heat, there is only one thermodynamic phase transition separating the low field and field reinforced phase of UTe2.

[1] Ran, S. et al. Science **365**, 684-687 (2019).

[2] Rosuel, A. et al. PRX **13**, 011022 (2023).

11:10 – 12:30 Skyrmions – Chair A. Huxley

11:10 – 11:40 **Koji Kaneko**, Magnetic skyrmion lattice in Eu-based f-electron magnets *(invited talk)*

Magnetic skyrmion, particle-like topologically non-trivial spin textures, attracts surge of interests from both fundamental and application points of view. Since the first discovery in a 3d-based magnet MnSi crystallizing in the cubic space group P213, intensive researches on magnetic skyrmions have been conducted so far. This leads to findings of new class of materials, and that extend to f-electron magnets in recent days. Here I would like to present our discovery on prototypical system EuPtX. EuPtX has the cubic chiral structure which belongs to the same space group as MnSi. The magnetic skyrmion lattice emerges at the intermediate field-temperature region in the B-T phase diagram when a magnetic field is applied to particular direction. In contrast to 3d-based compounds, magnetic skyrmions in f-electrons possess several unique characteristics, such as short periodicity and strong anisotropy. I will present microscopic insights into magnetic skymions in EuPtX and related compounds probed via neutron and x-ray scatterings.

11:40 – 12:10 **Alexandre Pourret**, Transport properties in the magnetic phases of non-centrosymmetric materials *(invited talk)*

We have studied transport properties in two non-centrosymmetric materials, EuPtSi and CeCoGe3. The chiral antiferromagnet EuPtSi presents different real space topological magnetic phases below the Néel temperature TN=4.05K. In particular, for H parallel to [111], it exhibits the well-known skyrmion lattice A-phase inside the conical phase between T=0.45K and T_N in the field range from 0.8T to 1.4T. Remarkably, the skyrmion lattice state in EuPtSi, composed of nanoscale skyrmions, can be extended down to very low temperature (lower than 0.1K) through field-cooling regardless of the cooling rate and of the magnetic history. Similarly, the metastability of the A'- and B-phase (H parallel to [100]) at low temperature is evidenced by our measurements. The antiferromagnetic Kondo lattice system CeCoGe3 undergoes an anti-ferromagnetic transition at TN1 = 21K, followed by two more transitions at TN2 = 12 K and TN3 = 8K. Three consecutive metamagnetic transitions were observed for magnetic field applied along the easy magnetic c-axis. We observed a large anomalous Nernst signal associated with the peculiar k-space topology in this material.

12:10 – 12:30 **Revaz Ramazashvili**, Texture-induced spin-orbit coupling and skyrmion-electron bound states in a Néel antiferromagnet

We derive an effective-mass electron Hamiltonian for a Néel antiferromagnet in the presence of a smooth texture of the staggered magnetization. For certain locations of electron band extrema, the texture produces a peculiar and anomalously strong spin-orbit coupling of the scale v/L, with v the Fermi velocity and L the characteristic length scale of the texture. For a skyrmion texture, this coupling generates electron bound states, whose energy scale is given by the gap in the electron spectrum. We study these bound states and, in certain limits, find their dependence on the geometry of the texture, and estimate the bound-state contribution to its energy. This contribution proves significant compared with the purely magnetic energy, and thus substantially influences the shape of the texture. It also considerably shifts the transition line between the modulated and the uniform phase in favor of the latter.

[1] N. Davier, R. Ramazashvili, Phys. Rev. B 107, 014406 (2023).

[2] N. Davier, R. Ramazashvili, Phys. Rev. B 109, 224425 (2024).

14:20 – 16:10 CeSb2 and URu2Si2 – Chair A. Severing

14:20 – 14:50 Atsushi Miyake, Magnetization easy axis switch phenomena in CeSb2 *(invited talk)*

CeSb2 has a two-dimensional orthorhombic crystal structure (space group: Cmce) with Sb layers and CeSb layers stacked along the c-axis, exhibiting multiple magnetic orders below 15.5 K. It has been reported that when a magnetic field is applied in the ab-plane at low temperatures, multiple metamagnetic transitions occur [1]. Recently, pressure-induced superconducting transitions were discovered [2]. We succeeded in growing single crystals of CeSb2 with a residual resistivity ratio exceeding 400 using the Sb self-flux method. Interestingly, the magnetization values along the a and b axes show strong sample dependence. Moreover, our field-angular dependent magnetization measurements suggested a possible existence of a field-induced phase transition around 20 T along the principal a and b axes. To reveal the higher field effect on CeSb2, we performed high-field magnetization measurements up to 50 T at 4.2 K. Prior to the high-field measurements, we measured the saturated magnetization values above 2 T as approximately 0.5 μB/f.u. (H || a) and 1.5 μB/f.u. (H || b) at 4.2 K. Surprisingly, magnetization for H || a increased sharply around 34 T, exhibiting a large hysteresis during demagnetization. Following this, intriguing phenomena unfolded. The saturation magnetization significantly increased to 1.7 μB/f.u., despite unchanged metamagnetic transition fields. This large, saturated magnetization proved robust against magnetic fields up to at least 50 T. Continuing measurements with H || b by changing the sample alignment at room temperature, we observed a surprising suppression of saturated magnetization above 2 T to approximately 0.3 μB/f.u. from 1.5 μB/f.u. More surprisingly, a substantial jump occurred at 30 T, accompanied by hysteresis in magnetization and enhanced saturated magnetization in subsequent measurements, similar to H || a measurements. These observations suggest that the applied magnetic field direction becomes the magnetization easy axis and the perpendicular direction the hard axis, with magnetic memory effects up to room temperature. Polarized microscopy revealed the presence of domains where the a-axis and b-axis were swapped depending on the location. It was found that the magnetization values depend on the sample, reflecting the distribution of domains. The magnetic memory effect likely arises from detwinning by the magnetic field.

[1] S. L. Bud'ko et al., Phys. Rev. B 57, 13624 (1998).

[2] O. P. Squire et al., Phys. Rev. Lett. 131, 026001(2023).

14:50 – 15:20 Hisashi Kotegawa, Nuclear quadrupole resonance study of pressure-induced superconductor CeSb2 *(invited talk)*

Recently, superconductivity was discovered in CeSb2 in the vicinity of a magnetic quantum critical point [1]. The superconducting transition temperature, Tc, is approximately 0.2 K, and the field dependence of Tc shows an inverted S shape, beyond the Pauli limit. These features suggest that a fascinating mechanism works for the superconductivity under magnetic fields.

CeSb2 crystalizes in a centrosymmetric orthorhombic structure with a space group Cmce. This structure lacks local inversion symmetry around the Ce site. CeSb2 shows antiferromagnetic (AF) transition at 15.5 K and successive transitions at ambient pressure. Applying pressure induces a structural transition at around 1.5 GPa, above which the Kondo effect becomes dominant. Another AF transition, which appears at the high-pressure phase, reaches 0 K at ~3 GPa. Superconductivity appears in the vicinity of this quantum phase transition. We performed Sb-nuclear quadrupole resonance measurements under pressure to reveal the electronic state behind the occurrence of superconductivity. At ambient pressure, the spectrum shows that the asymmetric parameter of the electric field gradient at the Sb site is almost zero, even though it is not protected by orthorhombic symmetry. This indicates that the electronic state of CeSb2 is close to tetragonal symmetry. We will show the pressure dependence of the spectrum and the nuclear spin relaxation rate, discussing characteristic points of CeSb2. If time allows, I will show another topic: anomalous Hall effect arising from f-electron antiferromagnetism.

[1] O. P. Squire at al., Phys. Rev. Lett. 131, 026001 (2023).

15:20 – 15:50 **Shinsaku Kambe**, NMR/NQR study of hidden ordering under uniaxial stress in URu2Si2 *(invited talk)*

Understanding of "hidden ordering" in URu2Si2 has progressed recently [1], but the definitive answer is still missing. Considering the recent experimental results, a few possible space groups have been selected for the hidden order symmetry [2,3]. The corresponding multipolar order parameter is spontaneously determined once the hidden order space group is determined. In this study, to find the correct one in the possible cases, the local symmetry of the Ru and Si sites is determined in the hidden order state under uniaxial stress along the [100] and [110] directions up to ~0.5GPa through precise NMR/NQR measurements. We will present discussions about determining the hidden order symmetry based on uniaxial measurements and group theoretical considerations.

[1] J. Mydosh et al, J. Phys.: Condens. Matter 32 (2020) 143002.

[2] S. Kambe et al, Phys. Rev. B, 97 (2018) 235142.

[3] S. Kambe et al, JPS Conf. Proc., 30 (2020) 011035.

15:50 – 16:10 **Karel Prokes**, Incommensurate field-induced phases in U(Ru0.98Rh0.02)2Si2 single crystal studied by neutron diffraction in pulsed fields up to 40 T

We report the high-field induced magnetic phases and phase diagram of a high-quality U(Ru0.98Rh0.02)2Si2 single crystal determined using neutron diffraction in pulsed magnetic fields up to 40 T [1]. High-field magnetization measurements show for the c-axis direction with increasing field, three induced magnetic phase transitions at Hc1 = 31.95 T, Hc2 = 35.45 T and Hc3 = 37.10 T. Magnetic structures above Hc1 and Hc2, respectively are characterized (apart from a ferromagnetic component) by a propagation vector Q2 = (0.63 0 0) that differs from propagation vectors found in the case of pure system [2] and systems with higher Rh doping [3,4]. Possibility of a creation of a double-Q between Hc2 and Hc3 is discussed. The state above Hc3 is clearly field-polarized state in agreement with magnetization data.

References

[1] F. Duc, X. Tonon, J. Billette, et al., Rev. Sci. Instr. 89, 053905 (2018).

[2] W. Knafo, F. Duc, F. Bourdarot, et al., Nat. Comm. 7, 13075 (2016).

[3] K. Kuwahara, S. Yoshii, H. Nojiri, et al., Phys. Rev. Lett. 110, 216406 (2013).

[4] K. Prokes, M. Bartkowiak, O. Rivin, et al., Phys. Rev. B 96, 121117(R) (2017).

16:40 – 18:20 UTe2 III – Chair Y. Tokunaga

16:40 – 17:10 **Michal Valiska**, Lattice dynamics of UTe2 in high magnetic fields studied by ultrasound *(Invited talk)*

We present a study of high-quality single crystals of UTe2 with Tc=2 K employing ultrasound and magnetostriction measurements performed in high magnetic pulse fields up to 60 T and down to 0.4 K [1]. Careful analysis of the data for four different accessible modes C33, C44, C55, and C66 allowed us to reveal the dramatic softening at the Critical End-Point (CEP) found in UTe2. It is the finite phase region where the first-order metamagnetic transition placed at 35 T for the field applied along the b axis changes to a broad cross-over transition to the field-polarized paramagnetic state at an elevated temperature of around 8 K. This is in agreement with the previous high-field studies of magnetoresistance and magnetization [2,3] where CEP was also detected. We follow the similar softening of the elastic constants at CEP in another itinerant f-electron system where the applied magnetic field induces the metamagnetic transition - UCoAl. We further traced the signatures of changes in the selected elastic constants Cij of UTe2 connected to the entering of the superconducting state at a low temperature below Tc and a magnetic field below Hc2. Comparative ultrasound measurements of the elastic constants were performed with the magnetic field applied in the b-c plane tilted by 30° to see the imprint of the high-field-induced superconducting phase which exists confined in the polarized paramagnetic state. These results bring further information to the magnetic field phase diagram of UTe2 and the possible symmetries of its superconducting phases.

[1] M. Valiska, arXiv:2307.01884 (2023)

[2] A. Miyake et al., J. Phys. Soc. Jpn. 88 (2019) 063706

[3] W. Knafo et al., J. Phys. Soc. Jpn. 88 (2019) 063705

17:10 – 17:40 **Toni Helm**, Field-induced compensation of magnetic exchange as the origin of high-field superconductivity in UTe2 *(invited talk)*

The potential spin-triplet heavy-fermion superconductor UTe2 exhibits signatures of multiple distinct superconducting phases. For field aligned along the b axis, a metamagnetic transition occurs at µ0Hm = 35 T. It is associated with magnetic fluctuations that may be beneficial for the field-reinforced superconductivity surviving up to Hm. Once the field is tilted away from the b towards the c axis, a reentrant superconducting phase emerges just above Hm. In order to better understand this remarkably field-resistant superconducting phase, we conducted magnetic-torque and magnetotransport measurements in pulsed magnetic fields. We determine the record-breaking upper critical field of $\mu_0 H_{c2}$ = 73 T and its evolution with angle. Furthermore, the normal-state Hall effect experiences a drastic suppression indicative of a reduced band polarization above Hm in the angular range around 30° caused by a partial compensation between the applied field and an exchange field. This promotes the Jaccarino-Peter effect as a for the reentrant superconductivity above Hm [1,2].

[1] Niu, Q., Knebel, G., Braithwaite, D., Helm, T., et al. Evidence of Fermi surface reconstruction at the metamagnetic transition of the strongly correlated superconductor UTe2. Phys. Rev. Res. 2, 033179 (2020)

[2] Helm, T., Kimata, M., Sudo, K., et al. Field-induced compensation of magnetic exchange as the possible origin of reentrant superconductivity in UTe2. Nat Commun 15, 37 (2024).

17:40 – 18:00 **Timothée Vasina**, High-field and high-pressure superconducting phases in UTe2 probed by ac-calorimetry in pressure cells

UTe2 is a novel unconventional heavy-fermion superconductor that has been gaining a lot of attention for the past five years. It presents a spectacularly high critical magnetic field compared to its critical temperature, much above the Pauli limit, as well as multiple superconducting phases hinting to the existence of spin-triplet superconductivity [1]. Previous results of ac-calorimetry showed that when applying a magnetic field along the b-axis, UTe2 exhibits a second, field-reentrant superconducting phase (HF), at around 15 T [2]. When subjected to hydrostatic pressure above about 0.3 GPa, UTe2 presents another superconducting phase (SC2) at zero field, up to a pressure of about pc = 1.6 GPa, the quantum critical point at which superconductivity disappears, and antiferromagnetic order appears [3, 4]. Many questions remain open, requiring the knowledge of the phase diagram of the superconducting phases under pressure with magnetic field applied along different crystallographic directions. For instance, whether or not the pressured-induced SC2 phase and the ambient pressure HF phase are connected is a crucial point, yet to be unambiguously determined. Some earlier results, such as Tunnel Diode Oscillator (TDO) measurements [5], and NMR studies [6], have already hinted in favour of this hypothesis. However, thermodynamic evidence of the link between the HF and SC2 phases as a function of pressure was still lacking to this date. Indeed, probing transitions between different superconducting states requires a thermodynamic probe like specific heat, rather than just transport measurements. To this end, in this work, we report results of three separate sets of ac-calorimetry measurements carried out on new generation Molten Salt Flux (MSF)-grown UTe2 samples. Our results are consistent with one another and unambiguously show that the HF phase continuously evolves into SC2 as pressure is gradually applied, meaning that these two phases are the same. These results provide additional ground for future experimental and theoretical work to finally determine the nature of high-field/pressure superconductivity in UTe2.

References:

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[2] Rosuel et al., Phys. Rev. X, 13 (2023) 011022

[3] Braithwaite et al., Commun. Phys., 2 (2019) 147

[4] Knafo et al., arXiv:2311.05455

[5] Lin et al., npj Quantum Mater., 5, 68 (2020)

[6] Kinjo et al. , Sci. Adv., 9, 30 (2023)

Wednesday 16 October

9:00 – 10:40 U compounds – Chair H. Suderow

9:00 – 9:30 **Stéphane Raymond**, Magnetic structure of the Kagome metal UV_6Sn_6 *(invited talk)*

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The Kagome network plays an essential role in condensed matter physics. In insulators, it has been one of the hallmark geometries in the field of frustrated magnetism leading to new exotic spin liquid states. In recent years, a new focus was given on Kagome metals where a distinctive band structure is achieved involving Dirac points, van Hove singularities and flat bands [1]. This leads to electronic instability and non-trivial topological effects observed in different families of Kagome metals. Representative examples of such states are, among others: superconductivity in CsV_3Sb_5 [2], anomalous Hall effect in Fe_3Sn_2 [3], and a charge density wave in ScV_6Sn_6 [4]. In this context, the family RV_6Sn_6, with R a rare earth element, has developed significant interest. In these systems, R is located in a triangular lattice at proximity to the Kagome network of non-magnetic V sites. While the Fermi surface is dominated by d-orbitals arising from the Kagome lattice, f-orbitals bring localized magnetic degrees of freedom that result in a complex interplay with the Kagome metals physics. Extending further this idea from rare earths to actinides, UV_6Sn_6 has been discovered in CEA-Grenoble and single crystals have been synthetized. Specific heat, magnetization and resistivity measurements indicate an antiferromagnetic ground state. Neutron diffraction measurements were undertaken to reveal the corresponding magnetic ordering. The crystallographic structure of UV_6Sn_6 is also discussed in the context of the variety of superstructures found in 1-6-6- ternary systems [5].

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[2] B.R. Ortiz et al., Phys. Rev. Lett. 125 (2020) 247002.

[3] H.W. Suriya Arachchige et al., Phys. Rev. Lett. 129 (2022) 216402

[4] L. Ye et al., Nature 555 (2018) 638.

[5] G. Venturini, Z. Kristallogr. 221 (2006) 511.

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9:30 – 10:00 **Andrew Huxley**, Half quantum vortices. A robust non-fermi liquid state and unconventional superconductivity *(invited talk)*

The talk will review the motivation behind our study of uranium diauride (UAu2), namely the search for superconductors that may host mobile half quantum vortices. Some numerical simulations of such vortices will be presented, along with a brief discussion of how they might be used in a quantum computer. UAu2 has a stacked triangular lattice leading to frustrated magnetic exchange interactions. It forms an unusual incommensurately modulated magnetic and charge state that displays non-fermi liquid properties at very low temperatures. The magnetic order is suppressed with pressure and superconductivity occurs just above the critical pressure. The talk will look at possible causes of the non fermi-liquid behaviour and examine whether the superconductivity indeed may have the right form to host half quantum vortices.

[1] Non-fermi liquid behaviour below the Neel temperature in the frustrated heavy Fermion magnet UAu2. Christopher D. O'Neill, Julian L Schmehr, Harry D. J. Keen, Luke Pritchard Cairns, Dmitry A Sokolov, Andreas Hermann, Didier Wermeille, Pascal Manuel, Frank Kruger and Andrew D. Huxley, Proceedings of the National Academy of Sciences of the United States of America, 118, 49 (2021)

[2] Multicomponent odd-parity superconductivity in UAu2 at high pressure, Christopher D. O'Neill, Julian L. Schmehr, and Andrew D. Huxley, Proceedings of the National Academy of Sciences of the United States of America, 119, 51 (2022)

10:00 – 10:20 **Somesh Kalaiarasan**, Electrical resistivity study on UGe2 under intense magnetic field

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UGe2 crystallizes in orthorhombic structure with the space group Cmmm (No. 65). It manifests anisotropic ferromagnetic behavior with a Curie temperature TC = 53 K and an ordered moment µm = 1.4 µB/U along the easy a-axis [1]. The ferromagnetic state is comprised of two FM phases: FM1 (weak magnetic moment) and FM2 (strong magnetic moment) separated by a cross-over at the characteristic temperatures Tx = 30 K. UGe2 becomes superconducting under pressure and unlike conventional superconductors, superconductivity in UGe2 emerges in the ferromagnetic phase [2]. Few studies of UGe2 were performed under a high magnetic field revealing the absence of metamagnetic transition up to 27 T [3]. We present the electrical resistivity study of UGe2 under intense magnetic fields up to 60 T in a wide temperature range 0.5 - 100 K. Investigations have been performed in different magnetic field directions in order to characterize the anisotropic magnetic properties of UGe2.

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10:20 – 10:40 **Callum Stevens**, Incommensurate charge density wave order and superconductivity in U2Ti

Density functional theory predicted that the ground state of U2Ti should undergo a Peierls-like doubling of its unit cell along the c-axis on cooling from high temperature [G. Kaur et al., J. Alloys Compd. 730, 36 (2018)]. X-ray diffraction, heat capacity, and resistivity measurements showing that with decreasing temperature the transition from the parent hexagonal structure occurs in two steps, via an incommensurate state below 71.1) K which then undergoes a lock-in transition to the predicted commensurate Peierls-like state at 46.3) K. Resistivity measurements under pressure indicate a suppression of the CDW ordering temperatures. The signatures of the upper transition in thermodynamic and transport measurements are weak, meaning that similar incommensurate charge density waves (ICDWs) preceding CDWs might occur more widely in other systems but elude detection. Despite previous reports of superconductivity at ambient pressure in U2Ti [M.B. Maple et al., Physica B+C, 135, 430 (1985)], heat capacity and resistivity measurements indicate the material is not a bulk superconductor. The collinear nature of both the ICDW and Peierls-like states is much simpler than more complex incommensurate states seen in

11:10 – 12:40 CeRh2As2 – Chair S. Ran

11:10 – 11:40 **Javier Landaeta**, Weak Competition between Superconductivity and the Phase I Order in CeRh2As2 *(invited talk)*

CeRh2As2 is a locally non-centrosymmetric heavy-fermion superconductor with a Tc = 0.320 K [1] and it is one of the few materials showing multiple superconducting phases. When a magnetic field is applied along the crystallographic c axis, a transition at H* = 4 T is observed that separates two superconducting states, SC1 and SC2. The upper critical field is extremely large Hc2 = 14 T given the low critical temperature. When the field is applied perpendicular to the c axis, only the SC1 phase is observed with Hc2 = 2 T. The superconducting phase diagram, as well as its angle dependence, can be explained with a superconducting parity switching scenario where the Rashba spin-orbit coupling plays a fundamental role [2]. At T0 = 0.45 K [3], a phase transition is observed into a so-called Phase I, the nature of which is currently a subject of debate. It is speculated to be quadrupolar [3] and/or magnetic in nature [4, 5]. The ongoing debate about the nature of Phase I and its potential influence on superconductivity underscores the need for further research. Particularly, there is no conclusive information from thermodynamic properties at ambient pressure on the question whether the H* transition at 4 T inside superconductivity is due to the competition or interplay between Phase I and superconductivity. Here, we show thermal expansion, magnetostriction, magnetization, and ac susceptibility measurements in CeRh2As2, samples of higher quality with a Tc = 0.35 K and T0 = 0.55 K. We observe an additional transition inside SC2 at H0 = 7 T in magnetostriction, magnetization, and ac-susceptibility, while the H* transition remains at 4 T. This H0 transition inside the superconducting state is a continuation of T0 in the normal state that is detected above Tc by thermal expansion, resistivity and specific heat measurement. We argue that this phase diagram points to a weak interaction of competitive nature between Phase I and superconductivity. We also highlight that the H* transition remains unchanged at 4 T independent of sample quality, and the parity switching explanation is still satisfactory.

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[2] J.F. Landaeta et al., Phys. Rev. X 12, 031001 (2022)

[3] D. Hafner et al., Phys. Rev. X 12, 011023 (2022)

[4] S. Khim et al., arXiv:2406.16575v2

[5] B. Schmidt and P. Thalmeier, arXiv:2404.10510v1

11:40 – 12:10 **Konstantin Semeniuk**, Exposing quantum criticality and odd-parity superconductivity in CeRh2As2 with hydrostatic pressure *(invited talk)*

The Kondo-lattice compound CeRh2As2 is a multi-phase heavy-fermion superconductor with the critical temperature of 0.35 K. Applying a 4 T magnetic field along the c axis of the teragonal unit cell triggers a transition between the low-field and high-field superconducting states SC1 and SC2 [1], which have so far been regarded, respectively, as phases of even and odd parity of the superconducting order parameter [2]. In the absence of magnetic field, the superconductivity is preceded by another ordered state Phase I [3,4]. The microscopic nature of Phase I is currently unknown, with magnetic and quadrupolar orders proposed as candidates. Along with the unique superconducting phase diagram, CeRh2As2 exhibits remarkably strong electronic correlations and pronounced non-Fermi-liquid behaviour. While in many Ce-based Kondo systems these are usually associated with a proximity to a magnetic quantum critical point, it has so far remained unclear whether the same exact scenario applies to CeRh2As2. By tuning structural and electronic properties of CeRh2As2 with hydrostatic pressure, we explored the interplay and relative stability of the ordered states of the system. We found that Phase I vanishes at a 0.5 GPa pressure, giving rise to a quantum critical point which is the source of pairing mediating fluctuations and extremely high quasiparticle masses [5]. The dome of the superconducting phase extends over a surprisingly large pressure range, with the critical temperature only reduced to about 0.2 K at 3 GPa. We also observed an unexpectedly rapid pressure-induced suppression of the superconducting phase switching field, leading to a stabilisation of the putative odd-parity state with respect to the even-parity one [6].

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12:10 – 12:40 **Daniel Agterberg**, Superconductivity with strong spin-orbit coupling: application to CeRh2As2 *(invited talk)*

A field induced, possibility topological, odd-parity superconducting state has been predicted and likely discovered in CeRh2As2 [1]. Here, after summarizing early results on the interplay of spin textures and superconductivity, I present recent results on CeRh2As2, emphasizing the connection between non-symmorphic symmetries and strong spin-orbit coupling [2]. General properties of the relationship between hidden spin-textures, non-symmorphic symmetries, and superconductivity will also be discussed [3]. Finally, I will present recent results on the role of interactions enhanced by quasi-2D Van Hove singularities on the superconducting and magnetic states in CeRh2As2 [4]. This work is supported by the US Department of Energy, Office of Basic Energy Sciences, Division of Materials Sciences and Engineering under Award DE-SC0021971.

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14:30 – 15:50 Yb and La – Chair S. Kambe

14:30 – 15:00 **Takahiro Onimaru**, Incommensurate modulation and magnetic anisotropy in an effective spin-1/2 zigzag chain of YbCuS2 *(Invited talk)*

In the magnetic semiconductor YbCuS2, Yb3+ ions with a 4f13 configuration form a zigzag chain in an orthorhombic structure (Pnma, #62) [1]. YbCuS2 undergoes a first-order phase transition at To = 0.95 K, which remains robust against magnetic fields up to 4 T, with To increasing to 1.5 K at 7 T [2]. We have conducted high-resolution powder neutron diffraction experiments at low temperatures down to 0.2 K and in magnetic fields up to 13 T. Upon cooling below To in a zero magnetic field, we observed weak magnetic peaks with an incommensurate propagation vector of k = [0, 0.305, 0]. An analysis of the diffraction pattern revealed that the Yb moments are aligned with an elliptical helix modulation along the zigzag chain, with the small components on the ac plane of μa = 0.19(1) and μc = 0.11(1) μB/Yb. This incommensurate modulation strongly suggests the development of spin nematic correlation due to an anisotropic term anticipated by theoretical calculations [3,4]. When a magnetic field of 7.5 T is applied, magnetic peaks with the commensurate propagation vector of k = [0, 1/3, 0] appear, indicating manifestation of the up-up-down alignment, which is a characteristic quantum phase of spin-1/2 in the zigzag chain. We have recently measured magnetic torque using thin single-crystalline samples with a length of approximately 50 μm. Our results confirmed that the magnetic susceptibility follows the order of χa > χc > χb. Thereby, the a- and b-axes are the easy and hard magnetization axes, respectively, which are perpendicular and parallel to the zigzag chain. This magnetic anisotropy is consistent with the magnetic structures determined by the neutron diffraction measurements at the magnetic fields of 0 and 7.5 T.

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15:00 – 15:30 **Yoshiki Sato**, Large transverse thermoelectric conversion induced by the dimensionality of Fermi surface *(Invited talk)*

The transverse thermoelectric (TTE) effect, the conversion between longitudinal heat current and transverse electric current, has attracted much attention as it offers remarkable potential beyond conventional thermoelectric devices [1-3]. Currently, the most promising TTE materials are magnetic compounds with topologically non-trivial band structures. Here, we propose to utilize the dimensionality of Fermi surfaces as a new approach to developing high-performance TTE materials. In this study, we focus on the chiral crystal LaPt2B [4] as a candidate material for efficient transverse thermoelectric conversion induced by mixed-dimensional Fermi surfaces [5]. We find that LaPt2B exhibits positive thermopower for out-of-plane direction and negative thermopower for in-plane direction, namely an axis-dependent conduction polarity. The calculated Fermi surfaces of LaPt2B include quasi-1D hole and quasi-2D electron Fermi surfaces, and the mix-dimensional Fermi surfaces are closely related to the observed axis-dependent conduction polarity. We demonstrated the large transverse thermopower (10 μV/K at T = 300 K) induced by the axis-dependent conduction polarity in the mixed-dimensional conductor. We will also discuss the investigation of the Fermi surface topology using quantum oscillations and related TTE materials based on the mixed-dimensionality of Fermi surfaces.

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Thursday 17 October

9:20 – 10:40 Eu and La compounds – Chair T. Onimaru

9:20 – 9:50 **Luigi Paolasini**, The Paganini's violin “the Cannone”: history, music and science *(invited talk)*

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The conservation of ancient violins of historical and cultural interest like the Paganini's “Cannone”, the well celebrated violin built by Giuseppe Antonio Guarneri in 1743, require a constant inspection of the status of structural integrity of the wood and the bonding parts, and an invaluable method to determine with non-destructive analysis the presence of micro-fractures of disconnections are X-rays. In particular the multi-resolution propagation phase contrast X-ray micro-tomography (PPC-SR-µ-CT) developed at BM18 beamline provides the optimal compromise between the image resolution and the intensity contrast, and is able to eventually guide the lute makers to realise restoration interventions. We will introduce the history of this very unique violin played by Niccolo Paganini all along his carrier across Europe, and we show in particular how by X-rays we can reconstruct the original structure of this violin, discovering the ingenious of Guarneri del Gesu in building an innovative instrument with a unique powerful voice.

9:50 – 10:20 **Motoi Kimata**, Nonreciprocal transport in noncentrosymmetric antiferromagnets - probing spin texture and hidden symmetry breaking *(Invited talk)*

The physical properties in noncentrosymmetric materials have been attracting much attention in recent years. The nonreciprocal resistance, where the resistance is not equivalent depending on the current polarity, is a typical example of cross-correlation response in symmetry broken metals, and this effect is closely related to the spin-polarized electronic structures due to the symmetry breaking. In this study, we report the results of nonreciprocal transport in noncentrosymmetric f-electron magnets EuIr4In2Ge4 and NdRu2Al10, and show that this technique could be an effective method to investigate symmetry broken electronic structures. EuIr4In2Ge4 is an antiferromagnetic (AF) semiconductor with symmetry broken tetragonal structure. From the band structure calculation, the spin-split Fermi surface with Dresselhaus-type spin texture is expected, but has not been confirmed experimentally. To probe the spin texture of this material, we performed nonreciprocal magnetoresistance experiment under rotating magnetic field by using a focused ion beam microfabrication technique to measure the precise anisotropy of nonreciprocal magnetoresistance for different crystalline axis. We show that the results of angle-resolved nonreciprocal magnetoresistance experiment are consistent with the expectation from Dresselhaus spin texture. This means that the present method is established as a new approach to determine the bulk spin texture of symmetry broken metals. The second material NdRu2Al10 is a magnetic metal hosting zigzag structure of Nd magnetic ion. Although the spatial inversion symmetry is globally preserved in this material, the symmetry is locally broken due to zigzag structure. In such materials, both time reversal and spatial inversion symmetries are expected to be broken if the spins on the zigzag chain are antiferromagnetically ordered with the wavevector of q = 0 along the chain. However, this AF state does not have no net magnetization, and thus the conventional magnetic measurements or Hall effect cannot detect the breaking of time reversal symmetry. In this study, we have performed nonreciprocal resistance experiment of this material to detect the hidden symmetry breaking since the observation of nonreciprocal resistance requires breaking of both time reversal and spatial inversion symmetries. We show that the nonreciprocal signal appears below the AF order, meaning that the time reversal symmetry is broken even in the net magnetization is zero. We also propose the AF domain dependence of nonreciprocal resistance, which could be useful for an electrical readout of AF domains.

10:20 – 10:40 **Maria Victoria Ale Crivillero**, Exploring the Enigma of Colossal Magnetoresistance in new Eu-based compounds: Insights from macroscopic to atomic length scales

The Colossal Magnetoresistance effect (CMR) entails a drastic, several orders of magnitude, decrease in the resistivity upon exposure of the respective material to a magnetic field. This phenomenon illustrates the complex coupling between different degrees of freedom in correlated electronic systems. Recently, novel Eu-based CMR materials such as Eu5In2Sb6 [1], EuCd2P2 [2], and EuZn2P2 [3] have been discovered. Notably, these compounds exhibit antiferromagnetic ground states, unlike previously known CMR materials characterized by ferromagnetic ordering. In these systems, intrinsic (i.e., non-chemical) electronically inhomogeneous states were observed well above the Curie temperature, associated with the formation of ferromagnetic clusters, the so-called magnetic polarons (MP). These compounds can also be an excellent playground for exploring the interplay of topology with magnetism. For instance, theoretical studies suggested that Eu5In2Sb6, which crystalizes in a non-symmorphic space group, may exhibit topological surface states [4,5]. To determine the appropriateness of a polaronic scenario for Eu5In2Sb6, we performed exhaustive experimental research combining STM/S characterization with bulk magnetic, thermodynamic, and electronic transport measurements [6-8]. We will also present recent findings on EuCd2P2.

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11:10 – 12:20 UTe2 IV – G. Knebel

11:10 – 11:40 **Yo Tokunaga**, NMR study of spin fluctuations and superconductivity in UTe2 *(invited talk)*

Our measurements of Te NMR relaxations reveal an enhancement of electronic spin fluctuations above 15 T, leading to their divergence in the vicinity of the metamagnetic transition at 35 T, below which field-reinforced superconductivity appears when a magnetic field is applied along the crystallographic b-axis [1]. The NMR data evidence that these fluctuations are dominantly longitudinal, providing a key to understanding the peculiar superconducting phase diagram in H//b, where such fluctuations enhance the pairing interactions.

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11:40 – 12:00 **Thomas Halloran**, Connection between f-electron correlations and magnetic excitation in UTe2 through inelastic neutron scattering

Enormous attention has been attracted recently by UTe2 due to its potential for realizing spin-triplet superconductivity. What little is known regarding the underlying magnetic interactions and excitations is gathered from previous inelastic neutron scattering studies. We present the results of a recent neutron study performed on a mosaic of single crystalline samples of superconducting UTe2. The magnetism in UTe2 is likely key to the formation of its exotic spin-triplet superconducting ground state, thus its magnetic excitations, as measured by this experiment, are informative in the context of phenomena related to the correlated electron effects such as Kondo hybridization. From the results of this measurement, the detailed anisotropy of the low-energy magnetic excitations in the candidate spin-triplet superconductor UTe2 has been characterized. The magnetic excitations emerge from low energy transfer at the high symmetry Y and T points, and disperse along the crystallographic a and b axes. In the presence of a c-axis magnetic field, these excitations are found to be field independent up to relatively high field scales of 11 T. The scattering captures all the expected magnetic moment for U3+, suggesting that we have captured all magnetic excitations in the measurement. We interpret the character of the scattering to indicate that the excitations originate from interband spin excitations arising from f-electron hybridization, which is supported by dynamical mean field theory calculations.

12:00 – 12:20 **Tristan Thebault**, Reinforcement of electronic correlations at the metamagnetic transition of UTe2 in a magnetic field in the (b-c) plane

The interplay between magnetism and unconventional superconductivity in UTe2 was extensively studied in the past few years [1-2]. Multiple superconducting phases were found to be induced in the vicinity of a metamagnetic transition under magnetic field either at ambient pressure or combined with pressure [3-6]. The re-entrant superconducting phase induced for a magnetic field in the (b,c) plane requests magnetic fields higher than 40 T which can be only accessed in high magnetic fields facilities [7]. Here we present a study of the electrical resistivity of UTe2 under a rotating field in the hard magnetization plane (b,c) which was performed at the LNCMI-Toulouse. The critical temperature of the field-induced superconducting phase is measured for different angles. The quadratic coefficient A, extracted with a Fermi liquid analysis, is studied in the vicinity of the different superconducting phases. Its relation with the stabilization of superconductivity and the development of critical magnetic fluctuations is discussed.

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14:00 – 15:10 High fields & 2D – Chair I. Sheikin

14:00 – 14:30 **Fabienne Duc**, Neutron Diffraction in Pulsed Magnetic Fields up to 40 T *(invited talk)*

Over the past two decades, there have been significant advancements in neutron diffraction performed in high magnetic fields, with experiments now pushing boundaries to fields as high as 40 T. This progress stems from the development of specialized pulsed field devices, using either short or long duration pulsed magnets [1, 2]. These breakthroughs surpass the limitations of current superconducting and resistive installations available at neutron sources, enabling the exploration of novel field-induced states. However, conducting diffraction measurements in high magnetic field environments remains a challenging task, demanding careful topic selection and expert preparation for successful campaigns at neutron sources. In this presentation, I will provide an overview of the 2 K/40-T pulsed field-cryomagnet collaboratively developed by LNCMI-Toulouse, ILL-Grenoble, and CEA-Grenoble. This magnet has been in successful operation since 2015, serving the community on the triple-axis CRG-CEA spectrometer IN22 at the ILL. Through a selection of results, I will demonstrate the capabilities of this setup and delve into the technical challenges encountered. Moreover, I will discuss necessary improvements essential for routine investigations of materials with small magnetic moments, such as high Tc superconductors or quantum spin systems.

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14:30 – 14:50 **Fedor Balakirev**, Near-Room Temperature Superconductivity under Extreme Pressures and Intense Magnetic Fields

Multiple classes of new materials exhibiting desired functionalities can benefit from the combination of extreme pressures and high magnetic fields. Recent reports of high-temperature superconductivity at temperatures as high as 260 K in hydrogen-rich compounds in high pressure conditions re-invigorated the quest for room-temperature superconductivity, a major scientific and technological frontier. Transforming pure molecular hydrogen with the aid of pressure into a superconductor has been a long-standing challenge and the subject of contention for the high-pressure community. We controllably tune and probe several hydride high-temperature superconductor families, including sulfur hydrides and rare earth "superhydrides" at the combined extremes of megabar pressure and 65 Tesla high magnetic fields. The advances in high pressure and high field experimental techniques enabled a host of thermodynamic and transport measurements that were not thought possible or compatible with a pulsed magnetic field environment. We employ high magnetic fields to induce phase transition from superconducting state in high-Tc hydrides to determine the key superconducting parameters, elucidate the details of superconducting coupling, and explore the pathways for increasing superconducting transition temperature and reducing the pressure required to stabilize the superconductivity.

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14:50 – 15:10 **Mostafa Marzouk**, Superconductivity and Ferromagnetism Coexistence in Two dimensional Electron Gases

Interfaces between two distinct materials can give rise to novel properties and unconventional functionalities not inherent to either constituent. Here, we demonstrate that at the interfaces between a non-magnetic band insulator and an antiferromagnetic layer, two-dimensional electron gases (2DEGs) form along different faces of the substrate. Interestingly, these faces exhibit ferromagnetism for the first time. Remarkably, through transport measurements, supported by x-ray magnetic circular dichroism and density functional theory calculations, we observed an exotic coexistence of superconductivity and ferromagnetism in these 2DEGs. This phenomenon is an intrinsic feature of the interfaces, not of the individual layers. our observation presents a novel candidate for co-hosting both superconductivity and ferromagnetism, which facilitates understanding the behavior of exotic superconductivity in these systems. In my talk, I will provide a detailed discussion on the evidence of superconductivity and ferromagnetism coexistence at the interface, as well as explore the possible origins that explain this phenomenon.

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16:00 – 19:00 Posters

P1 **Akihiro Minamide**, Phase diagram and novel vortex state in superconductors with sublattice degrees of freedom

Since the discovery of heavy-fermion superconductors and high-Tc superconductors, vigorous efforts have been made to extend the BCS theory and find unconventional superconducting states by incorporating additional degrees of freedom of Cooper pairs. In recent years, superconductivity in locally noncentrosymmetric crystals [1] has attracted more attention. Among them, a heavy-fermion superconductor CeRh2As2 [2] is particularly interesting in that it shows a phase transition inside the superconducting phase. This phenomenon is understood theoretically as the superconducting parity transition [3], where the even-parity superconducting state changes to the odd-parity one upon increasing the magnetic field. Almost all the previous theoretical studies on locally noncentrosymmetric superconductors have focused on the pure Pauli limit, and the effect of the vortex lattice formation has only been treated phenomenologically. However, since the parity transition occurs under the magnetic field, a theory of the vortex state is required for quantitative comparison between theory and experiment. In our study [4], theory of superconducting parity transition is extended by incorporating the vortex degree of freedom. We employ bilayer Rashba model representing locally noncentrosymmetric layered superconductors and derive the Ginzburg-Landau free energy functional. This formulation reveals parity transition and the H-T phase diagram of CeRh2As2 is quantitatively reproduced. Furthermore, a novel superconducting state with a meron (half-skyrmion) lattice pseudospin texture is predicted.

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P2 **Tetiana Haidamak**, High field study of UTe3

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UTe3 is one of the representatives of binary uranium chalcogenides UTx(T=S,Se,Te). Large single crystals of this compound were grown by the chemical vapor transport method. It crystalizes in the monoclinic structure of the ZrSe3 type The single crystals of UTe3 can be easily exfoliated and peel into layers confirming the presence of the Van der Waals bonds between the chalcogenide layers along the c-axis inside the unit cell. Our heat capacity measurements confirmed, that UTe3 is an antiferromagnet with TN=5K [1]. Its electrical resistivity increases exponentially with decreasing temperature followed by a sudden drop at 10 K Our high-field magnetization measurements up to 60 T revealed a metamagnetic transition at 20 T for the field applied along the a* axis.

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P3 **William Knafo**, Incommensurate antiferromagnetism in UTe2 under pressure

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The discovery of multiple superconducting phases in UTe2 boosted research on correlated-electron physics [1,2,3,4]. The proximity to a ferromagnetic quantum phase transition was initially proposed as a driving force to triplet-pairing superconductivity [1], and this heavy-fermion paramagnet was rapidly identified as a reference compound to study the interplay between magnetism and unconventional superconductivity with multiple degrees of freedom. Here, we present neutron diffraction experiments showing that long-range incommensurate antiferromagnetic order is established in UTe2 under pressure [5]. The propagation vector km = (0.07,0.33,1) of the observed antiferromagnetic phase is close to a wavevector where antiferromagnetic fluctuations have previously been observed at ambient pressure [6,7]. Our work shows that superconductivity in UTe2 develops in the vicinity of a long-range antiferromagnetic phase, which differs from the initial proposition of a nearby ferromagnetic phase. The nearly-antiferromagnetic nature of UTe2 at ambient pressure and its relationship with superconductivity will be discussed.

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P4 **Georg Knebel**, Field-enhancement of superconductivity in UTe2 under magnetic field

Unconventional superconductivity in UTe2 attracts strong attention due to the exciting superconducting properties and the extremely high upper critical field [1]. For a magnetic field along the b axis reentrant superconductivity is stabilized up to a 1st order metamagnetic transition. By specific heat, thermal expansion and magnetostriction measurements we show that the high-field reentrant and the low-field superconducting phases are separated by phase transition for a magnetic field applied b [2]. We show that the field enhancement of superconductivity is strongly influenced by the sample quality. Studies of the angular dependence of the upper critical field on the new very clean flux grown single crystals, with superconducting transition Tc = 2 K, show that the high-field superconducting phase extends in angle up to more than 20 degrees in the bc plane and connects to the field-induced superconducting phase SC3, which occurs above the metamagnetic transition in the field polarized state. We will also discuss recent progress in the determination of the Fermi surface by SdH, torque and dHvA experiments.

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P5 **Arno Hiess**, Current and future experimental possibilities for investigating actinide-based materials with neutrons

Since many decades neutron-based scattering and non-scattering techniques have significantly contributed to our understanding of actinide-based compounds. Due to the unique properties of neutrons these experimental possibilities remain invaluable to gain microscope insights and are complementary to other techniques including x-ray scattering [1]. We will recall some scientific examples with an emphasis on intermetallic quantum materials: Concerning unconventional superconductivity, inelastic neutron scattering revealed signature of superconductivity in the spin dynamics e.g. 'superconducting resonance' of U(Pd/Ni)2Al3 [2], UBe13 [3] and UTe2 [4]. Small Angle Neutron Scattering was used to investigate the flux line lattice in UPt3 [5]. Concerning exotic magnetism, neutrons revealed the NpO2 multipolar order [6], UO2 quadrupolar excitations [7], USb excitation above TN [8] and URu2Si2 dotriacontapole order [9] and field-induced spin-density wave beyond hidden order [10]. Polarised neutrons probed PuCoGa5 and NpCoGa5 electronic states [11]. The instrument suite for neutron scattering experiments at the Institut Laue Langevin (ILL) has significantly evolved in recent years which provides unprecedented possibilities also for research into actinide materials. We will present some recent instrumentation developments mainly related to cold neutron (direct and indirect) spectroscopy but also (polarised neutron) diffraction. Actinide research relies heavily on the scientific support infrastructure and all proposals for ILL beamtime will be evaluated for technical feasibility and safety. A large range of sample environment is available for uranium-based compounds. For transuranium experiments a special low temperature insert is available with a base temperature of 5K. The neutron eco-system is constantly evolving and the European Spallation Source (ESS) will start neutron production next year. ESS shall provide user access to some instruments from 2027 onwards. We will highlight their unique instrument suite providing new experimental possibilities. Again, a range of scientific support infrastructure will be available as required for an (initial) user programme.

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P6 **Ryuji Hakuno**, Magnetism and superconductivity in the two-sublattice periodic Anderson model for UTe2

UTe2 is a strong candidate for a spin-triplet superconductor [1] because of its extremely high upper critical field well above the Pauli limit [1,2], and multiple superconducting phases appear when a magnetic field or pressure is applied [3]. UTe2 had been considered to be a spin-triplet superconductor mediated by ferromagnetic fluctuations from the results of magnetization measurements and theoretical study based on the periodic Anderson model[4]. However, subsequent neutron scattering experiments detected antiferromagnetic fluctuations instead of ferromagnetic fluctuations. Since antiferromagnetic fluctuations generally stabilize spin-singlet superconductivity rather than spin-triplet superconductivity, the need to reconsider the relationship between magnetic fluctuations and the superconducting state has been recognized. In this study, we theoretically investigate magnetic fluctuations and superconductivity based on the microscopic model. The quasi-two-dimensional Fermi surfaces have been reported from de Haas-van Alphen experiments in UTe2, and first-principles calculations suggest that they are mainly composed of one-dimensional conduction electrons [5]. On the other hand, first-principles calculations and several experimental results have proposed the existence of three-dimensional Fermi surfaces in addition to these Fermi surfaces. Thus, in the previous study, we constructed a mixed-dimensional periodic Anderson model in which one-dimensional and three-dimensional Fermi surfaces coexist as described above and analyzed magnetic fluctuations and superconducting instabilities [6]. There, the coexistence of antiferromagnetic fluctuations and spin-triplet p-wave superconductivity was revealed. However, UTe2 has a crystal structure with two sublattices in each unit cell and no inversion center at the U site, i.e. a locally non-centrosymmetric superconductor [7]. This property induces sublattice-dependent antisymmetric spin-orbit coupling leading to anisotropy of magnetic fluctuations and superconducting order parameters with spin degrees of freedom. In this study, we extend the previous model by considering the existence of multiple sublattices and spin-orbit coupling. Based on the model analysis using the Eliashberg theory and RPA, we discuss the origin of magnetic fluctuations and superconductivity and the relationship between them.

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P7 **Pablo Garcia Talavera**, Direct observation of a pair density wave in the high field phase of FeSe

FeSe is a low carrier density superconductor with a critical temperature of about 9 K and a large critical field of 17 T. Above about 15 T, several features in thermodynamic measurements suggest the appearance of a new superconducting phase [1]. It has been conjectured that this phase has a modulated superconducting state, or a pair density wave, following the proposal of Fulde Ferrel Larkin Ovchinikov (FFLO) state [2,3]. Here we make a detailed Scanning Tunneling Microscope (STM) study of the high field superconducting phase of FeSe. We find that the Zeeman effect leads to an energy shift for spin up and spin down quasiparticles which can be followed as a function of the magnetic field. We discuss the vortex lattice from 8 T to 15 T, where we observe modulations of the charge density with a periodicity which depends on the magnetic field as the inverse square root. This charge density modulation has topological defects for bias voltages outside the superconducting gap, of 1.9 meV, but is homogeneous inside the gap, showing that the modulation is a new form of pair density wave. The observed magnetic field dependence suggests that the new pair density wave is caused by open Landau quantized cyclotron orbits in the periodic lattice of Abrikosov vortices.

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P8 **Meike Pfeiffer**, Pressure-tuned quantum criticality in the locally non-centrosymmetric superconductor CeRh2As2

The heavy-fermion superconductor CeRh2As2, Tc = 0.35 K, has attracted a lot of attention due to the existence of two different superconducting states in magnetic field applied along the crystallographic c axis of the tetragonal crystal structure [1]. The two superconducting states are currently understood as even- and odd- parity states, respectively [2]. In addition, the compound hosts an ordered phase below T0 = 0.5 K, believed to be a quadrupole density wave order [3]. We apply hydrostatic pressure to study the unconventional nature of the superconductivity and its interplay with the T0 order by conducting electrical resistivity measurements on CeRh2As2 down to 30 mK, in magnetic fields up to 18 T and at hydrostatic pressures up to 2.7 GPa [4]. We trace the pressure evolution of the T0 order and the superconducting phases for the magnetic field applied in the basal plane and along the crystallographic c direction. The T0 order is highly sensitive to lattice compression and is completely suppressed to zero temperature already at P0 = 0.5 GPa [5]. The rate of suppression determined by electrical resistivity is about -1 K/GPa, which is confirmed by complementary heat capacity measurements under pressure in zero magnetic field. The superconducting transition temperature initially increases with pressure and peaks close to the critical pressure P0. Above P0, Tc decreases down to 0.23 K at 2.7 GPa and both superconducting phases persist up to the highest pressure applied. The fact that both superconducting phases persist well above the pressure where T0 is suppressed suggests that the T0 order is not responsible for the phase switching from the even to the odd parity state. However, superconductivity in CeRh2As2, as in other unconventional superconductors, emerges around a QCP induced by the suppression of the T0 order.

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P9 **Liu Hao Tjeng**, Why different spectroscopies give seemingly different answers on U compounds

A central issue in the research field of uranium-based materials is the charge state of the U 5f since it provides a necessary starting point to model the chemical and physical properties of these materials. Numerous spectroscopic studies have been carried out, utilizing a wide range of methods such as photoelectron spectroscopy (PES, ARPES, RPES), x-ray absorption spectroscopy (XAS, XMCD, HERFD), x-ray Raman spectroscopy, and RIXS. Yet, there is a considerable debate and confusion in the community since different methods give seemingly different answers about the U 5f valency. Here we argue that the different methods should give the same answer. The key ingredient is that the analysis of the spectra must include explicitly electron correlation effects at the U sites. An interpretation in terms of one-electron density of states and convolutions thereof with various core level or added states is not sufficient and leads to erroneous results. Instead, one must at least use a configuration-interaction based approach in order to arrive at a consistent and unified picture, and include the quantum interference effects that occur when analyzing the intensities of the various peaks in the spectra.

P10 **Jeremy Sourd**, Probing Lifshitz transitions in the quasi-1D heavy fermion compound YbNi4P2 with ultrasound

The quasi-1D heavy fermion compound YbNi4P2 has attracted lots of theoretical and experimental interest, due to its proximity to a ferromagnetic quantum critical point and due to the cascade of Lifshitz transitions induced by the magnetic field. In this poster, we show how ultrasound can help to characterize better the field induced transitions, by probing elastic modes of different symmetry.

P11 **Kumar Sudhanshu**, Temperature-dependent neutron diffraction and magnetic studies on magnesium ferrite (MgFe2O4) powder prepared via sol-gel auto combustion method using DL-alanine fuel

The present work investigates both crystallographic and magnetic structures of post-annealed magnesium ferrite (MgFe2O4) powder using Neutron diffraction within temperature range (10-300K), and obtained the variations in the crystallite and domain size both shows a good correlation with the changes in magnetic properties (as determined via using temperature dependent magnetic measurements). Further, studies their magnetic behaviour under zero-field cooling (ZFC) and field-cooling (FC) conditions through the vibrating sample magnetometer and found to be the ferrimagnetic nature of MgFe2O4 powder. Also, the Magnetic domain size (Dm) decreases with decreasing temperature, although the variation in crystallite size is negligible with decrease in measurement temperature. This obtained decrease in domain size with decreasing temperature is because of increase in coercive field (HC). Furthermore, the magnetic moments for one magnesium ferrite (MgFe2O4) molecule have estimated through the Rietveld refinement of neutron diffraction patterns, and finally magnetic moment calculated from saturation magnetization which shows good agreement.

P12 **Maxime Leroux**, Superconducting critical current measurements in pulsed magnetic field up to 60T

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The promises of all-superconducting DC magnets that could reach continuous and stable magnetic fields above 40 T have been motivating research in high-temperature superconducting coated conductors for very high-field applications. This effort has led to the recent demonstration of 32+ T all-superconducting magnets and similar milestones at several high-field laboratories worldwide.[1,2,3]

Such magnets require superconducting wires or tapes that retain significant current carrying capacity (critical current, J_c) even at these very high magnetic fields. The value of J_c at high magnetic fields is set by the interplay between vortex-vortex and vortex-defects interactions, but the larger the magnetic field, the larger the number of vortices and the greater the challenge to keep them pinned.

The high field Jc of *RE*-$Ba_2Cu_3O_7$ tapes (*RE* = rare-earth) which have been used for the 32+T all-superconducting magnets, can be improved by the addition of artificial pinning centers (APC), yet the limit of vortex pinning in superconductors at fields above 40 T is almost uncharted territory. In fact, with critical fields in excess of 150 T at 2K, less than 20% of REBCO's potential H-T phase diagram has been explored.

Jc measurements are indeed limited to ~36 T in resistive coils and 45 T in hybrid coils[4]. To go beyond requires to use pulsed magnetic fields [5]. To that aim, we have been developing a superconducting critical current measurement setup in pulsed fields up to 60 T, with possibility of an extension to 70 T.

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P13 **Daniel Braithwaite**, High pressure studies in pulsed magnetic field

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Pressure is a powerful tuning parameter for strongly correlated electron systems, especially in association with the other extreme conditions of low temperature and high magnetic fields. Combining high pressure with static magnetic field is quite common, even up to the highest static magnetic fields available in dedicated facilities. But if even higher magnetic field is required, only pulsed magnetic fields are available, and combing high pressure techniques with pulsed fields presents specific challenges, especially if low temperatures are required. In a collaboration between CEA Grenoble, CNRS LNCMI Toulouse, and Niigata university, we developed a pressure cell to perform magneto-transport measurements under pressure up to 6 GPa, in pulsed magnetic fields up to 60T and at temperatures down to 1.4K[1]. We present the performance of the technique with some examples of studies in the systems $CeRh_2Si_2$[2], URu_2Si_2[3] and UTe_2[4].

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P14 **Marc Nardone**, Cryogenic developments at the LNCMI-T

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The LNCMI is a CNRS laboratory providing users with access to very high magnetic fields and specific scientific instrumentation.

In this context, the LNCMI-T cryogenics team has, over the years, developed different equipment allowing scientific measurements at very low temperatures. Here we present the metallic-plastic cryostats used in our facilities such as He4 bath cryostats, pumped He3 insets, He3-He4 Dilution refrigerators and the helium liquefier commissioned in 2020 at LNCMI-T.

Friday 18 October

9:00 – 10:50 UTe2 V – Chair M. Zhitomirsky

9:00 – 9:30 **Youichi Yanase**, Theoretical studies of multiple superconducting phases in CeRh2As2 and UTe2 *(invited talk)*

Superconductors with multicomponent order parameters are platforms for exotic symmetry breaking and topological superconductivity. Among several candidates, the recent discovery of CeRh2As2 and UTe2 has attracted much interest, motivated by the observation of multiple superconducting phases indicating multicomponent superconducting order parameters. I will discuss our recent work to clarify the multiple superconducting phases in CeRh2As2 and UTe2. The parity transition scenario in CeRh2As2 will be discussed with a focus on antiferromagnetic quantum criticality [1] and topological superconductivity [2]. I will also show a recent study of the vortex phase diagram [3], which indicates a fractional vortex phase identified as a topological meron state. Linear and nonlinear paraconductivity is proposed as an all-electric experimental probe of the parity transition [4]. For UTe2, spin-triplet superconductivity induced by antiferromagnetic and/or ferromagnetic fluctuation [5] is discussed. As a perspective, a mechanism of reentrant superconductivity in the magnetic field is proposed based on the odd-parity multipole fluctuation [6].

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9:30 – 10:00 **Satoshi Fujimoto**, Topology and multiple superconducting phases of UTe2 *(invited talk)*

We discuss topological aspects of spin-triplet superconductor candidate UTe2, and also a possible scenario for multiple superconducting phases of this material.

10:00 – 10:30 **Andriy Nevidomskyy**, Towards uncovering the mystery of the high-field superconducting phase in UTe2 *(invited talk)*

The recent experimental data in high magnetic field [1] showed that the field-induced superconducting phase wraps around the b axis in a halo-like fashion and appears to be stabilized by a field component perpendicular to the magnetic easy axis. In this talk, I will discuss the current theoretical understanding of this behaviour, which is believed to arise when a multicomponent spin triplet order parameter acquires a finite orbital moment of the Cooper pairs along the applied field direction. This conclusion, borne out of the phenomenological Landau-Ginzburg theory, imposes strong constraints on the d-vector of the order parameter.

Namely, the order parameter is likely to be (B2u+iB3u) for magnetic fields in the (bc) plane, and acquires an additional B1u component for fields tilted towards the a-axis.

[1] S.K. Lewin et al, High-Field Superconducting Halo in UTe2, arXiv:2402.18564 (2024)

10:30 – 10:50 **Jushin Tei**, Microscopic mechanism and pairing symmetries of multiple superconducting phases in UTe2

The potential spin-triplet superconductor UTe2 exhibits multiple superconducting phases under applied pressure [1]. The superconducting phase at ambient pressure is suppressed as applied pressure increases, whereas another superconducting phase appears under pressure. However, the symmetries of these superconducting phases are still controversial, and their origin remains unclear. To elucidate the nature of the multiple superconducting phases, we focus on the spin fluctuation-mediated pairing mechanism for UTe2. Since UTe2 exhibits a strong increase in spin susceptibility at low temperatures, the presence of ferromagnetic (FM) fluctuations is discussed [2]. Conversely, neutron scattering measurements have revealed the presence of antiferromagnetic (AFM) fluctuations [3]. Moreover, the observation of an AFM ordered phase above 1.5 GPa pressure has been reported [4]. From these perspectives, we postulate that the pairing glues are FM and AFM fluctuations, and their interplay controlled by pressure results in the emergence of multiple superconducting phases. Based on this scenario, we introduce a phenomenological model of pairing interactions mediated by both FM and AFM fluctuations and solve the Eliashberg equations. We compare the maximum eigenvalues of all irreducible representations to ascertain the stable pairing symmetry. In our numerical calculations [5], we consider cases where the interaction is mediated solely by Ising-FM or Ising-AFM fluctuations. For FM fluctuations, the Au and B3u states have the largest eigenvalues, with the predominant d-vector component being db (dc) for Au (B3u). Ising-FM fluctuations along the easy-axis (a-axis) stabilize the spin-triplet pairings with the magnetic moment along this axis. In the case of AFM fluctuations, the B1u state shows the largest eigenvalue, with the predominant d-vector component being da. This is attributed to Ising-AFM fluctuations along the easy axis, leading to an attractive interaction for the d-vector component along this axis due to Fermi surface nesting. Our results provide a comprehensive understanding of the multiple superconducting phases under pressure. The superconducting phase at ambient pressure is either the Au or B3u states induced by Ising-FM fluctuations, while the superconducting phase under pressure is the B1u state induced by Ising-AFM fluctuations.

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11:20 – 12:40 UTe2 VI – Chair D. Braithwaite

11:20 – 11:50 Sheng Ran, Revealing a 3D Fermi Surface and Electron-Hole Tunneling in UTe2 with Quantum Oscillations *(Invited talk)*

Spin triplet superconductor UTe2 is widely believed to host a quasi-two-dimensional Fermi surface, revealed by first-principles calculations, photoemission, and quantum oscillation measurements. An outstanding question still remains as to the existence of a three-dimensional Fermi surface pocket, which is crucial for our understanding of the exotic superconducting and topological properties of UTe2. This 3D Fermi surface pocket appears in various theoretical models with different physics origins, but has not been unambiguously detected in experiment. In this talk we will discuss our evidence for a relatively isotropic, small Fermi surface pocket of UTe2 via quantum oscillation measurements. In addition, we observed high frequency quantum oscillations corresponding to electron-hole tunneling between adjacent electron and hole pockets. The coexistence of2D and 3D Fermi surface pockets, as well as the breakdown orbits, provide a test bed for theoretical models and aid the realization of a unified understanding of the superconducting state of UTe2 from the first-principles approach.

11:50 – 12:20 Koichi Izawa, Quasiparticle Heat Transport and Gap Structure of Ultraclean UTe2 *(invited talk)*

Spin-triplet superconductivity is an intriguing topic in condensed matter physics because it carries a wide variety of novel phenomena, including topologically nontrivial properties. UTe2 is considered one of the most promising candidates for spin-triplet superconductors, showing an extremely high upper critical field Hc2 beyond the Pauli limit in all directions [1,2], reentrant superconductivity along the b-axis [3,4], and multiple superconducting (SC) phases under pressure and magnetic field [5]. A crucial aspect of understanding superconductivity is determining the symmetry of the SC pair function, as it is inherently reflected in the nature of pairing interactions. Although a great deal of effort has been made to clarify the nature of the superconductivity in UTe2 until now, the SC gap structure remains highly controversial. The main reason why the arguments are not settled is that most discussions on the gap structure have been made based on the temperature (T) dependence of physical quantities; the impurities easily modify the T dependence associated with the low-energy quasiparticle excitations, sometimes leading to misinterpretations of the gap structure. Therefore, comprehensive studies based on several measurements complementary to T dependence are strongly required to capture the intrinsic gap structure. In our talk, we present the findings from our research on the longitudinal thermal conductivity and thermal Hall conductivity of several crystals UTe2 with a residual resistivity ratio varying from 20 to more than 600 and discuss low-energy quasiparticle (QP) excitation and the pair function of this compound from multiple perspectives based on the results of not only temperature dependence but also field dependence, the residual T-linear term of thermal conductivity, and angular resolved thermal conductivity. Our findings strongly indicate that UTe2 is in a fully gapped superconducting state.

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12:20 – 12:40 **Zheyu Wu**, Mapping the rich superconducting phase diagram of ultraclean UTe2

The odd-parity superconductor candidate UTe2 hosts a wealth of exotic physical phenomena, including a variety of superconducting phases. Three distinct superconducting states have been observed at ambient pressure in high magnetic field experiments, while up to five separate superconducting phases have been reported from hydrostatic pressure measurements. This talk will discuss the phase diagram of UTe2 as measured on a new generation of pristine quality samples grown by a salt flux technique. I will outline our recent measurements to high magnetic fields at ambient pressure and under hydrostatic pressures in ambient field that reveal notable similarities and differences between the phase boundaries identified by our study with those reported from measurements on numerous samples of varying disorder level. The talk will conclude with a discussion on how the responses of different superconducting phase boundaries to varying levels of disorder in UTe2 can shed light on understanding their microscopic pairing mechanisms.

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