MaNEP: Correlations and topology in quantum matter

This session has been organised in collaboration with the Association MaNEP.

Tuesday, 27.08.2019, Room G 85

Time	ID	Correlations and topology in quantum matter I: Dynamics, magnetism and topology *Chair: Mark Fischer, Uni Zürich*
14:00	601	**Novel families of SU(N) AKLT states with arbitrary self-conjugate edge states** *Samuel Gozel [1], Didier Poilblanc [2], Ian Affleck [3], Frédéric Mila [1]* *[1] Institut de Physique, EPFL* *[2] Laboratoire de Physique Théorique, IRSAMC, Université de Toulouse* *[3] The University of British Columbia* Using the Matrix Product State framework, we generalize the Affleck-Kennedy-Lieb-Tasaki (AKLT) construction to one-dimensional spin liquids with global color SU(*N*) symmetry, finite correlation lengths, and edge states that can belong to any self-conjugate irreducible representation of SU(*N*). Families of local parent Hamiltonians can be constructed and allow us to study the stability of the edge states by interpolating between exact AKLT points. In particular we show that the topologically trivial phase of a spin-1 chain with spin-1 edge states can be reached from the original AKLT point through a continuous phase transition described by the $SU(2)_1$ WZW conformal field theory.
14:15	602	**Generating multiple universality classes and nodal loops in Chern insulators by periodic driving** *Paolo Molignini [1], Ramasubramanian Chitra [1], Wei Chen [2]* *[1] ETH Zürich, [2] PUC Rio* We investigate the topology of a periodically-driven two-dimensional Chern insulator hosting anomalous edge modes. Using a renormalization group approach on the stroboscopic Berry curvature, we obtain flow diagrams that clearly delineate all topological phase boundaries, therefore demonstrating that a detailed knowledge of the micromotion is not necessary to assess the appearance of the Floquet topological phase transitions. Furthermore, we characterized the critical behavior of the Floquet topological excitation by extracting the critical exponents of measurable diverging quantities. We discover that two different universality classes coexist in the same model: a class characterized by linear, Dirac-type gap closures and another outlined by quadratic gap closures associated with a low-energy theory described by a nodal-loop semimetal.
14:30	603	**Localization properties of the interpolating Aubry-André-Fibonacci model** *Antonio Štrkalj [1], Valentin Goblot [2], Jose L. Lado [1], Nicolas Pernet [2], Sylvain Ravets [2], Jacqueline Bloch [2], Oded Zilberberg [1]* *[1] ETH Zürich,* *[2] Centre de Nanosciences et de Nanotechnologies (C2N), CNRS, Université Paris-Sud, Université Paris-Saclay* Model Hamiltonians with quasicrystalline order display a hierarchy of phenomena at different scales and are excellent starting points to explore unconventional effects not achievable in conventional periodic solids. In this talk, I will present a theoretical study of the model that interpolates between two well-known quasiperiodic examples: Aubry-André and Fibonacci model. In particular, I will show the analysis of the localization properties of this model. We find that by controllably evolving an Aubry-André into a Fibonacci model, a series of localization-delocalization transitions take place before the spectrum becomes critical. Our findings provide new insights about the forming of criticality in quasiperiodic systems and open up new avenues to study the interplay among quasiperiodicity, topology, and interactions.

14:45	**604**	**4D topology in a dynamical 2D system** *Ioannis Petrides, Oded Zilberberg, ETH Zürich* Topological insulators are a novel state of matter which, to date, have seen a variety of manifestations. All available realizations, however, share a common feature: their spectral bands are attributed with a nonlocal index that is quantized. This unique topological property commonly manifests through exotic bulk phenomena and robust boundary effects. In this talk, I will present a foundamental 4D insulator and show the connection of the 2nd Chern number to the 0-dimensional localised states found in 2-dimensional 2nd-order TIs.
15:00	**605**	**Novel structural and electronic phases of 2D transition metal dichalcogenides** *Oleg V. Yazyev, EPFL* I will present our theoretical work that aims at revealing systematic trends and developing intuition across the entire family of 2D transition metal dichalcogenides (TMDs). I will address the relevance of the crystal and ligand fields in determining the relative stability of 1T and 1H polymorphs and introduce a unified picture of lattice instabilities (charge-density-wave and strong- coupling regime) in metallic TMDs. The rest of my talk will focus on two particular realisations of topological and magnetic phases. I will discuss the well-ordered 1T'-1H heterojunctions experimentally observed in WSe_2 in relation to the quantum spin Hall interface states and present the observation of magnetic ordering and magnetoresistive switching in few-layer $PtSe_2$ that realises a new scenario in magnetic 2D materials.
15:30	**606**	**Discovery and engineering of new topological quantum materials** *Niels B. M. Schröter, Paul Scherrer Institut* Topological quantum materials have become a ubiquitous topic in condensed matter physics over the past decade, but there is still plenty of room for new discoveries of exotic topological phases and improvements in device engineering. Here, I will report our achievements in thin film growth, soft X-ray angle-resolved photoemission spectroscopy (SX-ARPES), and scanning tunnelling microscopy and spectroscopy (STM and STS), to synthesize new materials and characterize and engineer their electronic properties, such as: 1. Tuning of the band offset at superconductor/semiconductor interfaces for applications in Majorana zero mode heterostructures. 2. Investigation of the interplay between chirality and Fermi-arc topography in chiral topological semimetals. 3. Synthesis and spectroscopy of a novel two-dimensional material with flat bands.
15:45	**607**	**Tunable Berry Curvature Through Magnetic Phase Competition in a Topological Kagome Magnet** *Zurab Guguchia [1], Joel Verezhak [1], Dariusz Gawryluk [2], Stepan S. Tsirkin [3], Jiaxin Yin [4], Ilya Belopolski [4], Huibin Zhou [8], Gediminas Simutis [1], Songtian Zhang [4], Tyler A. Cochran [4], Guoqing Chang [4], Ekaterina Pomjakushina [2], Lukas Keller [5], Zuzanna Skrzeczkowska [6], Qiang Wang [7], Lei Hechang C. [7], Rustem Khasanov [1], Alex Amato [1], Shuang Jia [8], Titus Neupert [3], Hubertus Luetkens [1], Zahid M. Hasan [4]* *[1] Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institut, CH-5232 Villigen PSI* *[2] Laboratory for Multiscale Materials Experiments, Paul Scherrer Institut, CH-5232 Villigen PSI* *[3] Department of Physics, University of Zurich, Winterthurerstrasse 190, 8057 Zürich* *[4] Laboratory for Topological Quantum Matter and Spectroscopy, Department of Physics, Princeton University, Princeton, New Jersey 08544, USA* *[5] Laboratory for Neutron Scattering, Paul Scherrer Institut, CH-5232 Villigen PSI* *[6] Faculty of Chemistry, Warsaw University of Technology, Noakowskiego 3, PL-00-664 Warsaw* *[7] Department of Physics and Beijing Key Laboratory of Opto-electronic Functional Materials and Micro-nano Devices, Renmin University of China, Beijing, China* *[8] Int. Center for Quantum Materials and School of Physics, Peking University, Beijing, China* Using muon spin-rotation experiments and density functional theory calculations, we present evidence for competing magnetic orders in a topological kagome magnet $Co_3Sn_2S_2$ [1]. Our results show that while the sample exhibits an out-of-plane ferromagnetic ground state, an in-plane anti-ferromagnetic state appears at temperatures above 90 K. Strikingly, the reduction of the anomalous Hall conductivity above 90 K linearly follows the disappearance of the volume fraction of the

		ferromagnetic state. We further show that the competition of these magnetic phases is tunable through applying either an external magnetic field or hydrostatic pressure. Our results taken together suggest that the magnetic competition drives the thermal and quantum evolution of Berry curvature field in $Co_3Sn_2S_2$, thus tuning its topological state. [1] Guguchia et.al., arXiv:1904.09353(2019).
16:00	**608**	**Do topology and ferromagnetism cooperate at the EuS/Bi_2Se_3 interface?** *Jonas A. Krieger [1,2], Yunbo Ou [3], Marco Caputo [1], Alla Chikina [1], Max Döbeli [2], Marius-Adrian Husanu [1], Itai Keren [1], Thomas Prokscha [1], Andreas Suter [1], Cui-Zu Chang [3,4], Jagadeesh S. Moodera [3], Vladmir N. Strocov [1], Zaher Salman [1]* *[1] Paul Scherrer Institut, [2] ETH Zürich, [3] MIT, [4] The Penn State University* We present our recent results on the local magnetic and electronic properties at the topological insulator/ferromagnetic insulator interface EuS/Bi_2Se_3, which was previously reported to exhibit magnetic proximity persisting up to room temperature [1]. We use antiresonant ARPES at the Eu M_5 pre-edge to access the interface electronic band structure. Low energy muon spin rotation reveals strong local magnetic fields extending several nm into Bi_2Se_3, below the magnetic transition of EuS. However, we find a very similar result upon replacing Bi_2Se_3 with titanium, implying that its origin is mostly independent of the topology of the involved layers [2]. [1] F. Katmis, et al., Nature 533, 513 (2016). [2] J. A. Krieger, et al., Phys. Rev. B 99, 064423 (2019)
16:15	**609**	**Ultrafast dynamics of the magnetic fluctuations in the spin-chain $CuGeO_3$** *Eugenio Paris [1], Christopher William Nicholson [2], Yi Tseng [1], Giacomo Coslovich [3], William Schlotter [3], Sioan Zohar [3], M. F. Lin [3], G. L. Dakovski [3], Claude Monney [2], Thorsten Schmitt [1]* *[1] Paul Scherrer Institut, [2] Université de Fribourg, [3] SLAC National Accelerator Laboratory* In the spin-chain compound $CuGeO_3$, the relation between charge, spin, and lattice degrees of freedom, giving rise to the Spin-Peierls transition, is still unclear. In this system, Resonant Inelastic X-ray Scattering (RIXS) at the O K-edge is capable of detecting charge-transfer excitations, including the formation of a Zhang-Rice singlet. The probability for such a non-local process depends on the magnetic correlations between two neighboring CuO_4 plaquettes. We use an ultrashort laser pump to excite carriers across the charge transfer gap, perturbing the local spin correlations by removing magnetic holes from the Cu site. With ultrafast O K-edge RIXS, we probe the suppression and recovery of the Zhang-Rice singlet, giving insight into the dynamics of the short-range magnetic correlations.
16:30		***Coffee Break***
		Correlations and topology in quantum matter II: Topological band structures *Chair: Johan Chang, Uni Zürich*
17:00	**611**	**Experimental results on the predicted Weyl semimetal PrAlGe** *Daniel Destraz [1], Stepan Tsirkin [1], Titus Neupert [1], Lakshmi Das [1], Yang Xu [1], Johan Chang [1], Andreas Schilling [1], Adolfo Grushin [2], Joachim Kohlbrecher [3], Lukas Keller [3], Pascal Puphal [4], Ekaterina Pomjakushina [4], Jonathan White [3]* *[1] Physik-Institut, Universität Zürich,* *[2] Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Neel* *[3] Laboratory for Neutron Scattering and Imaging, Paul Scherrer Institut* *[4] Laboratory for Multiscale Materials Experiments, Paul Scherrer Institut* Topological materials have many interesting properties and are the focus of intense theoretical and experimental research. The material PrAlGe has recently been predicted to be a Weyl semimetal with broken time reversal and inversion symmetries [1]. We present experimental results on various properties of PrAlGe single crystals such as magnetization, neutron diffraction, and electrical transport with a focus on the origin of the anomalous Hall and Nernst effects. This data is compared to theoretical calculations involving the Berry curvature of the Weyl nodes in the system. [1] Guoqing Chang et al., Phys. Rev. B 97, 041104(R) (2018)

17:15	**612**	**Low-energy band structure of Weyl-II candidate $MoTe_2$: a view from infrared spectroscopy** *Ana Akrap [1], David Santos-Cottin [1], Edoardo Martino [2], Florian Le Mardelé, [1], Fabian von Rohr [3], Zoran Rukelj [4]* *[1] University of Fribourg, [2] EPFL,* *[3] Department of Chemistry, University of Zürich, [4] University of Zagreb* 1T'-$MoTe_2$ is a layered, van der Waals material, which has recently been proposed to host Weyl fermions, linked to the tilted Dirac cones in its band structure. In this transition metal dichalcogenide, very fine energy scales play an important role. However, the precise low-energy structure of these bands has so far been experimentally elusive, due to a complex coexistence of several electronic bands at the Fermi level. We address the electrodynamics in $MoTe_2$ by exploring its temperature-dependent infrared properties. We identify two pronounced low-lying interband excitations, one of whom strongly shifts with temperature. Using a simple theoretical approach, we can discern the characteristics of the bands crossing the Fermi level, helping to demystify the band structure of 1T'-$MoTe_2$.
17:30	**613**	**Spin reorientation in ferromagnetic type-II Weyl Fe_3Sn_2** *Neeraj Kumar, Y. Soh, PSI Villigen* Fe_3Sn_2 is predicted to be a type-II Weyl semimetal which orders ferromagnetically below $T_C = 646$ K. It undergoes a spin reorientation transition (SRT) between 300 K - 100 K which together with recently shown coupling between its easy axis and the band structure paves the way of external control of its bulk properties. By probing anisotropic magnetoresistance, bulk magnetization and imaging the domain structure of Fe_3Sn_2 using XMCD-PEEM at different temperatures, we understand its domain structure together with evolution of easy axis during the SRT. We are able to clearly establish the nature of the SRT to be of first order. M. Yao et al. Switchable Weyl nodes in topological Kagome ferromagnet Fe_3Sn_2, arXiv 1810.01514 (2018).
17:45	**614**	**A comparative photoemission spectroscopy and scanning tunneling microscopy study of the topological material $ZrTe_5$** *Björn Salzmann, Maxime Rumo, Christopher William Nicholson, Thomas Jaouen, Fabiano Vanini, Ana Akrap, Phillipp Aebi, Claude Monney, Université de Fribourg* The low-energy electronic structure and topological nature of $ZrTe_5$ has recently been under debate with several contradictory results published. It consists of nearly linearly dispersing bands at the Gamma point with potentially a small band gap, making $ZrTe_5$ very sensitive to structural defects. However, only minor attention has been given to the influence of the sample growth method on the crystal quality and its physical properties. Here we present angle-resolved photoemission spectroscopy and scanning tunneling microscopy measurements performed on samples grown by the two different methods used for $ZrTe_5$ growth. We will focus on the presence of defects and discuss their influence on the low-energy electronic structure of $ZrTe_5$.
18:00	**615**	**Fractional corner charges in spin-orbit coupled crystals** *Marta Brzezińska [1,2], Frank Schindler [1,3], Wladimir Benalcazar [4], Mikel Iraola [5], Adrien Bouhon [6], Stepan Tsirkin [1], Maia Vergniory [5,7], Titus Neupert [1]* *[1] Department of Physics, University of Zürich* *[2] Department of Theoretical Physics, Wrocław University of Science and Technology* *[3] Kavli Institute for Theoretical Physics, University of California* *[4] Physics Department, Pennsylvania State University* *[5] Donostia International Physics Center* *[6] Department of Physics and Astronomy, Uppsala University; NORDITA* *[7] IKERBASQUE, Basque Foundation for Science* We investigate two-dimensional spinful bulk insulating phases of matter that are protected by time-reversal and crystalline symmetries. In order to characterize these systems, we use the concept of corner charge fractionalization and show that charges are both quantized and remain stable as long as all symmetries are preserved. To define the topology, we employ symmetry indicators and Wilson loop invariants. We illustrate our results using the example of arsenic and

		antimony monolayers. Depending on the degree of structural buckling these materials can exhibit two distinct obstructed atomic limits. We present tight-binding and density functional theory calculations for open flakes to support our findings.
18:15	**616**	**Hopf Insulators: Localized Representation and Observable Phenomena** *Aleksandra Nelson, Universität Zürich,* *Aris Alexandradinata, University of Illinois at Urbana-Champaign,* *Alexey Soluyanov, ETH Zürich* Despite being predicted more than a decade ago, Hopf insulators still have no realistic candidate material realization. The problem with finding such material is two-fold: Most importantly, the corresponding topological invariant - integer-valued Hopf number - is only defined for a two-band system, while another source of the problem stems from the assumed absence of any symmetry required to protect the Hopf phase. Apart from that, it is also not clear which properties of a Hopf insulator can be measured in order to find candidate compounds from the physical response. In this work, we address these problems and discuss physical aspects that should allow for the search of the Hopf insulator compounds.
18:30	**617**	**High-Pressure Growth of the Newly Predicted Quantum Spin Hall Insulator Pt_2HgSe_3** *Enrico Giannini, Céline Besnard, DQMP University of Geneva* A large-gap Quantum Spin Hall Insulating state was recently predicted to appear in the compound Pt_2HgSe_3. The lack of knowledge of phase equilibria in the Hg-Pt-Se system as well as the high-volatility and toxicity of the components render the conventional crystal growth methods unusable. Here we report on the successful growth of Pt_2HgSe_3 crystals at high pressure (1-3 GPa), using a cubic anvil isostatic press operating at high temperature (800 - 1000°C). The largest crystals (~0.9 × 0.5 mm^2 in the ab-plane) were grown at 1.5 GPa and 900°C, starting from a slightly Hg-rich composition. The crystals exhibit the expected structure and exfoliate in the ab-plane. The successful growth of jacutingaite crystals opens a new perspective towards robust non-trivial 2D topologic materials.
18:45	**618**	**Emergent topology in a 3D Kane-Mele system: Pt_2HgSe_3** *Irène Cucchi [1], Felix Baumberger [1], Enrico Giannini [1], Antimo Marrazzo [2], Marco Gibertini [1], Anna Tamai [1]* *[1] Université de Genève, [2] EPFL* Monolayer jacutingaite (Pt_2HgSe_3) was recently predicted to be a Kane-Mele Quantum Spin Hall insulator (QSHI), with a topological gap as large as 0.5 eV. We investigated the electronic band structure of bulk single crystals by angle-resolved photoemission. Surprisingly, on the (001) surface, we observed surface states dispersing over large areas of the Brillouin zone, which is unexpected from a 3D stack of 2D QSHI. Using a minimal description that extends the Kane-Mele model to 3D, we demonstrate that these states are topologically protected indicating that bulk Pt_2HgSe_3 realizes a new form of topological (quantum band) semimetal.
19:00		
19:30		***Public Lecture***

Time	ID	CORRELATIONS AND TOPOLOGY IN QUANTUM MATTER III: HETEROSTRUCTURES AND VAN DER WAALS MATERIALS *Chair: Oded Zilberberg, ETH Zürich*
14:00	621	**Strain-controlled dimensionality of interface metallicity in $LaVO_3$/$LaTiO_3$ multilayers** *Sophie Beck, Claude Ederer, ETH Zürich* Complex oxide thin films and heterostructures exhibit a wide variety of interesting functionalities at their interfaces, which are often not present in the corresponding bulk components. Here, we report on a metallic interface in multilayers of two Mott insulators, $LaVO_3$ and $LaTiO_3$, using a combination of density functional theory (DFT) and dynamical mean-field theory (DMFT). We show that the metallic layer results from charge transfer across the interface, which can be understood in terms of the electronegativity difference of the bulk materials. We demonstrate how expitaxial strain can be used to control the spatial extension of this layer, with tensile strain leading to a localization within a thickness of only two unit cells.
14:15	622	**$LaVO_3$ Thin Films under Epitaxial Strain** *Hugo Meley, DQMP, Université de Genève, 24, quai E.-Ansermet, CH-1211 Genève 4* Interplay between spin, charge, orbital and lattice degrees of freedom is extremely strong and at the origin of numerous phenomena in complex oxides [1]. The bulk 3d2 $LaVO_3$ showcases an interesting phase diagram where the low temperature orbital and spin ordering are strongly dependent upon the A cations size [2]. The $GdFeO_3$-type distortions remove the t2g degeneracy and modify the bandwidth to generate a Mott state. Above the transition temperature (140 K), $LaVO_3$ is a paramagnetic insulator while below, an orbital and spin order establishes [3]. The transition can be described mainly by one-dimensional orbital correlations between d_{xz} and d_{yz} states since the lowest energy d_{xy} orbitals have an occupation number close to one. We have explored different effects of biaxial strain in epitaxial thin films of $LaVO_3$. X-ray diffraction reveals that the layers accommodate the strain imposed by the substrate assuming different patterns of octahedral tilts and rotations. We used temperature dependent X-ray diffraction, muon spectroscopy and optical conductivity to investigate how the strain-induced crystal field splitting [4] alters the d-d orbital correlations. [1] D. I. Khomskii, Transition metal compounds (Cambridge University Press, 2014). [2] Y. Ren et al., Nature (London) 396, 441 (1998); Phys. Rev.B 67, 014107 (2003). [3] M. De Raychaudhury, E. Pavarini, and O. Andersen,Phys. Rev. Lett. 99, 126402 (2007). [4] G. Sclauzero, K. Dymkowski, and C. Ederer, Phys. Rev. B 94, 245109 (2016).
14:30	623	**A laser-ARPES study of $LaNiO_3$ thin films grown in-situ by sputter deposition** *Edoardo Cappelli [1], Siobhan McKeown Walker [1], Anna Tamai [1], Marta Gibert [2], Jean-Marc Triscone [1], Felix Baumberger [1], Flavio Yair Bruno [3], Willem Tromp [4]* *[1] Université de Genève, [2] University of Zürich,* *[3] Complutense University of Madrid, [4] University of Leiden* Thin films of the transition-metal oxide $LaNiO_3$ (LNO) undergo a metal-insulator transition when their thickness is reduced to 2-3 unit cells. Here, we use a state-of-the-art laser-ARPES setup to map the electronic structure of LNO thin films with improved resolution. A series of high-quality films of thicknesses ranging from 19 to 2 unit cells is grown by sputter deposition and transferred in vacuo to the ARPES setup. Our measurements show an unchanged Fermi surface for all metallic samples. However, the peak width of the momentum distribution curve at the Fermi level progressively increases as the thickness is reduced. This suggests that the metal-insulator transition is driven by the increasing importance of interfacial scattering and a reduced inelastic mean free path.

14:45	**624**	**High sensitivity variable-temperature infrared nanoscopy of conducting oxide interfaces** *Weiwei Luo, Margherita Boselli, Jean-Marie Poumirol, Ivan Ardizzone, Jérémie Teyssier, Dirk van der Marel, Stefano Gariglio, Jean-Marc Triscone, Alexey B. Kuzmenko* *Department of Quantum Matter Physics, University of Geneva* Probing the local transport properties of two-dimensional electron systems (2DES) confined at buried interfaces requires a non-invasive technique with a high spatial resolution operating in a broad temperature range. In this paper, we investigate the scattering-type scanning near field optical microscopy as a tool for studying the conducting $LaAlO_3/SrTiO_3$ interface from room temperature down to 6 K. We show that the near-field optical signal, in particular its phase component, is highly sensitive to the transport properties of the electron system present at the interface. Our model allows to quantitatively correlate changes in the optical signal with the variation of the 2DES transport properties induced by cooling and by electrostatic gating. Imaging conducting nano-channels reveals the high spatial resolution of the technique.
15:00	**625**	**Transport in sub-micrometric devices at the $LaAlO_3/SrTiO_3$ interface** *Margherita Boselli, Adrien Waelchli, Gernot Scheerer, Stefano Gariglio, Jean-Marc Triscone* *University of Geneva* The interface between $LaAlO_3$ and $SrTiO_3$ hosts a conducting two-dimensional electron system (2DES) characterized by several interesting properties. When the 2DES is confined in-plane to realize structures with a lateral size comparable to the characteristic length-scales of the system, mesoscopic effects emerge in electronic transport. Here, we present the properties of nanowires realized at the $LaAlO_3/SrTiO_3$ interface using the AFM-writing technique and hard masks of amorphous $SrTiO_3$. We found that their magnetoconductance show signatures of coherent transport up to 1.5 K, and that nanochannels narrower than 100 nm undergo a metal-to-insulator transition at ~30 K. We attribute this behavior to the reduced system size using a model based on the saddle-point approximation of a quantum point contact.
15:15	**626**	**Quantum Rings with Broken Symmetries** *Jochen Mannhart, Hans Boschker, Daniel Braak, Philipp Bredol* *Max Planck Institute for Solid State Research, DE-70569 Stuttgart* We present novel quantum rings, which for example are fabricated from Rashba materials. These rings make use of the little explored interface between quantum mechanics and classical physics – their function is based on quantum collapses of electron wave packets combined with the coherent evolution of the quantum states. The devices feature fascinating properties such as unidirectional transport of matter waves and information. In particular, they reveal a fundamental inconsistency between quantum physics (including collapse processes) and the second law of thermodynamics.
15:45	**627**	**Semiconducting van der Waals Interfaces as Artificial Semiconductors** *Evgeniy Ponomarev, Nicolas Ubrig, Ignacio Gutiérrez-Lezama, Alberto Morpurgo* *University of Geneva* The recent progress in the assembly of 2D van der Waals heterostructures has shown that it is possible to stack virtually every material out of this class enabling a truly unprecedented potential to discover new physical phenomena or to engineer novel electronic functionalities. Despite the vast scope of possibilities enabled by vdW interfaces, a systematic microscopic understanding allowing the interfacial electronic properties to be predicted in terms of those of the constituent monolayers is missing. Here, we develop a strategy based on band-alignment engineering which enables to build vdW interfaces which are either artificial semiconductors or artificial semi-metals. The results of optical and transport measurements demonstrate that the behavior of these interfaces is virtually indistinguishable from that of naturally existing 2D materials.

16:00	**628**	**Anomalous Hall Effect in the Quantum Limit in Exfoliated Crystals of the Layered Antiferromagnet $Co_{1/3}NbS_2$** *Giulia Tenasini [1], Nirmal J. Ghimire [2], Edoardo Martino [3], Laszlo Forro [3], Alberto F. Morpurgo [1]* *[1] DQMP and GAP, University of Geneva* *[2] Argonne National Laboratory, Materials Science Division, Argonne USA* *[3] Laboratory of Physics of Complex Matter, EPFL* The anomalous Hall effect (AHE) can arise even in systems without a net magnetization provided that certain common symmetries are absent. Here, we present experiments on the layered antiferromagnet $Co_{1/3}NbS_2$, which exhibits AHE below the Néel temperature T_N = 29 K in the bulk. Our transport measurements on micro-fabricated devices reveal a pronounced anisotropy in the resistivity – indicative of the two dimensional (2D) character of the electronic properties – and show an extremely large AHE with an anomalous Hall conductance exceeding e^2/h per layer at low temperature. This represents the first experimental observation of the AHE in the quantum limit in antiferromagnets, and – given the 2D nature of $Co_{1/3}NbS_2$ – suggests the presence of topological bands originating from the magnetic superstructure.
16:15	**629**	**Electrically-tunable flat bands and magnetism in twisted bilayer graphene** *Tobias Wolf, Jose L. Lado, Oded Zilberberg, Gianni Blatter* *Institute for Theoretical Physics, ETH Zürich* Twisted graphene bilayers provide a versatile platform to engineer metamaterials with novel emergent properties by exploiting the resulting geometric moiré superlattice. We show that tuning the twist angle to $\alpha^* \approx 0.8°$ generates flat bands with triangular superlattice periodicity. When doped with ±6 electrons per moiré cell, these bands are half-filled and electronic interactions produce a symmetry-broken ground state (Stoner instability) with spin-polarized regions that order ferro-magnetically. Application of an interlayer electric field breaks inversion symmetry and introduces valley-dependent dispersion that quenches the magnetic order. With these results, we propose a solid-state platform that realizes electrically tunable strong correlations.
16:30		***Coffee Break***
		Correlations and topology in quantum matter IV: Superconductors and parent electronic strucutres *Chair: Thomas Greber, Uni Zürich*
17:00	**631**	**Spin-orbit coupling and self energies in Sr_2RuO_4** *Anna Tamai, University of Geneva* We explore the interplay of electron-electron correlations and spin-orbit coupling in the model Fermi liquid Sr_2RuO_4 using laser-based angle-resolved photoemission spectroscopy. Our precise measurement of the Fermi surface confirms the importance of spin-orbit coupling and reveals that its effective value is enhanced by a factor of about two, due to electronic correlations. The self-energies for the β and γ sheets are found to display significant angular dependence, which arises from a substantial orbital mixing induced by spin-orbit coupling and does not imply momentum dependent many-body interactions. A comparison to single-site dynamical mean-field theory further supports the notion of dominantly local orbital self-energies, and provides strong evidence for an electronic origin of 'kinks' in the quasiparticle dispersion of Sr_2RuO_4.

17:30	**632**	**Three-dimensional Fermi surface of overdoped La-based cuprates** *Masafumi Horio [1], Kevin Hauser [1], Yasmine Sassa [2], Zarina Mingazheva [1], Denys Sutter [1], Kevin Kramer [1], Ashely Cook [1], Elisabetta Nocerino [3], Ola Forslund [3], Oscar Tjernberg [3], Masaki Kobayashi [4], Alla Chikina [4], Niels B. M. Schröter [4], Jonas Krieger [4], Thorsten Schmitt [4], Vladmir N. Strocov [4], Sunseng Pyon [5], Tomohiro Takayama [5], Hidenori Takagi [5], Oliver Lipscombe [6], Stephen Hayden [6], Motoyuki Ishikado [7], Hiroshi Eisaki [8], Titus Neupert [1], Martin Månsson [3], Christian Matt [1], Johan Chang [1]* *[1] University of Zürich, [2] Chalmers University of Technology, [3] KTH Royal Institute of Technology, [4] Paul Scherrer Institut, [5] University of Tokyo, [6] University of Bristol, [7] Comprehensive Research Organization for Science and Society, [8] National Institute of Advanced Industrial Science and Technology* We have performed soft x-ray angle-resolved photoemission spectroscopy (ARPES) measurements on overdoped La-based cuprates $La_{2-x}Sr_xCuO_4$ and $Eu_{0.2}La_{1.8-x}Sr_xCuO_4$, and investigated the band structure in three-dimensional momentum space. While nodal part of the Fermi surface was k_z independent, significant k_z-dispersion was unveiled in the antinodal portion. From the band structure fitted to the tight-binding model, we have demonstrated that the significant k_z-dispersion suppresses the enhancement of the density of states (DOS) by van-Hove singularity (VHS). Our results suggest that the enhancement of electronic specific heat observed in La-based cuprates is caused by quantum criticality rather than by simple DOS divergence at VHS.
17:45	**633**	**Electronic and magnetic tuning of charge order and phonon anomaly in a cuprate spin ladder** *Yi Tseng [1,2], Eugenio Paris [1], Wenliang Zhang [1], Rabindranath Bag [3], Vladmir N. Strocov [1], Surjeet Singh [3], Henrik M. Rønnow [2], Thorsten Schmitt [1]* *[1] Photon Science Division, Paul Scherrer Institut* *[2] Laboratory for Quantum Magnetism, Institute of Physics, EPFL* *[3] Indian Institute of Science Education and Research* Charge order (CO) and the connection to electron-phonon coupling (EPC) play crucial role in the low-energy regime of quasi-one-dimensional ladder materials. Characterizing the relevant excitations provides a direct tool to assess the underlying complex interactions. Resonant inelastic X-ray scattering (RIXS) is a powerful technique for probing phonons and its interplay with CO. We investigated the CO and optical phonon excitations in the two-leg ladder subsystem of $Sr_{14}(Cu,Co)_{24}O_{41}$ using O K-edge RIXS and X-ray absorption spectroscopy (XAS). We infer a continuous shift of the CDW ordering towards Γ-point with Co doping, with a 5 - 10 meV softening of the bond-stretching phonon mode (~65 meV) at the ordering vector. This is accompanied by a reduction in the ladder hole density determined from XAS.
18:00	**634**	**Ultra-High Resolution Neutron Spectroscopy of Low-Energy Spin Dynamics in UGe_2** *Marc Janoschek, Paul Scherrer Institut* Studying the prototypical ferromagnetic superconductor UGe_2 we demonstrate the potential of the Modulated IntEnsity by Zero Effort (MIEZE) technique — a novel neutron spectroscopy method with ultra-high energy resolution of at least 1 μeV — for the study of quantum matter. We reveal purely longitudinal spin fluctuations in UGe_2 with a dual nature arising from 5*f* electrons that are hybridized with the conduction electrons. Local spin fluctuations are perfectly described by the Ising universality class in three dimensions, whereas itinerant spin fluctuations occur over length scales comparable to the superconducting coherence length, showing that MIEZE is able to spectroscopically disentangle the complex low-energy behavior characteristic of quantum materials.
18:15	**635**	**Superconductivity without inversion and time-reversal symmetries** *Mark Fischer, University of Zürich, Manfred Sigrist ETH Zürich, Daniel F. Agterberg, University of Wisconsin-Milwaukee* In 3D, only time-reversal (T) and inversion (I) symmetries are essential for superconductivity. We examine the 2D case and find that T and I are not required, and having a combination of either symmetry with a mirror operation (M_z) on the basal plane suffices. Combining energetic and topological arguments, we classify superconducting states without T and I present, a situation encountered in several experimentally relevant systems. With only I combined with M_z, the system is

		generically fully gapped, potentially with topologically-protected chiral edge modes. All other cases do not support chiral Majorana edge states, but the superconductor can have point nodes with associated topologically-protected flat-band edge modes. Our analysis provides guidance on the design and search for novel 2D superconductors.
18:30	**636**	**Effect of electron count and chemical complexity in high-entropy alloy (HEA) superconductors** *Fabian O. von Rohr, University of Zürich, Robert J. Cava, Princeton University* HEAs are a new class of materials that consist of several principal elements arranged on simple lattices, stabilized by the high-configurational-entropy of the random mixing of the elements. In this presentation, we will show that the properties of this superconducting high-entropy alloy are strongly related to the valence electron count and that the superconducting transition temperatures T_c of these alloys fall between those of analogous crystalline and amorphous materials. We find that despite the large degree of randomness and disorder in these alloys, the superconducting properties are nevertheless strongly dependent on the chemical composition and complexity. We argue that high-entropy alloys are excellent model systems for understanding how superconductivity and other collective quantum states evolve from crystals to amorphous solids.
18:45	**637**	**Unconventional superconductivity with T_c = 30 K in stoichiometric ThFeAsN** *Toni Shiroka [1,2], Tian Shang [2], Nicolò Barbero [1], G.-H. Cao [3], I. Eremin [4], Joel Mesot [1], Hans-Rudolf Ott [1]* *[1] ETH Zürich, [2] Paul Scherrer Institut, Villigen* *[3] Department of Physics, Zhejiang University, China* *[4] Institut für Theoretische Physik III, Ruhr-Universität Bochum* The actinide superconductor ThFeAsN exhibits a T_c of 30 K without doping or external pressure. Formally similar to LaFeAsO and predicted to be an antiferromagnet, surprisingly, the new material does not show any magnetic order. Based on results of a series of ambient- and high-pressure experiments and DFT calculations [1,2], we show how ThFeAsN combines the peculiarities of unconventional superconductivity with those of correlated electron systems. We further compare the role of charge doping vs. structural distortions and argue why the “structural route” to superconductivity is so unusual in iron-based compounds. [1] T. Shiroka et al., Nature Comm. 8, 156 (2017). [2] N. Barbero et al., Phys. Rev. B 97, 140506(R) (2018).
19:00		***END; Postersession with Apéro***
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ID	MaNEP: Correlations and topology in quantum matter Poster
641	**Magneto-optical spectroscopy on TaAs** *David Santos-Cottin [1], Florian Le Mardelé [1], Edoardo Martino [2], Ana Akrap [1]* *[1] University of Fribourg, [2] EPFL* TaAs has been predicted to be a Weyl semimetal with a complex Fermi surface composed of two Weyl and one trivial hole pocket. It is not evident how to describe the low energy excitations. In order to reveal the details of the low energy electronic band structures of TaAs, we performed reflectivity measurements at zero field at various temperatures, as well as magneto-optical spectroscopy up to 34 Tesla at low temperature in the far and mid infrared regions. In a finite magnetic field, Landau level transitions dominate the optical spectra. As the character of the electronic bands determines the splitting of these Landau levels in field, the field dependence of the transitions reveals the electronic ground state of TaAs.

642 **Magneto-transport and optical conductivity of type II Weyl semimetals: $TaIrTe_4$**

Florian Le Mardelé [1], David Santos-Cottin [1], Edoardo Martino [2], Mario Novak [3]
[1] University of Fribourg, [2] EPFL, [3] University of Zagreb

3D Dirac and Weyl semimetals are the analogs of graphene which possess 3D linear dispersion around points in the Brillouin zone. Optical and transport studies are widely used in order to explore these compound. $TaIrTe_4$ is expected to be a Weyl semimetal that has the fewest Weyl points - 4 - in comparison to TaAs, which contains 12 pairs. It has been theoretically shown that $TaIrTe_4$ hosts type II Weyl cones. This type should appear when electron and hole pockets touch in one conical point. Electronic transport in magnetic field allows to identify effective masses, number of carriers and position of Fermi level with respect to the Weyl points. These measurements are complemented by optical conductivity of $TaIrTe_4$.

643 **Dynamical Structure Factor analysis of the Bilinear Biquadratic Spin-1 chain**

Mithilesh Nayak, Frédéric Mila, EPFL

The Bilinear-Biquadratic spin-1 chain (BLBQ) has been studied for its entangled ground states, diverse phases and topological properties. The natural language to study entanglement in strongly correlated systems is tensor networks. Using time dependent tensor network simulations, we demonstrate the dynamical spin and quadrupolar structure factors of the BLBQ model in ferro-quadrupolar dimer phase and antiferro-quadrupolar semi-ordered phase and compare them with the ones obtained from the analytical calculations using multi-boson approach. Interestingly, the system is analytically solvable for few points (Takhtajan Babujan, Uimin Lai Sutherland, Affleck Kennedy Lieb Tasaki points). We explore the analogy of the Biquadratic model in dimer phase with spin-1/2 XXZ model using Temperley Lieb Algebra and confirm it via structure factor plots obtained from simulations.

644 **Electronic Phase Transitions in Suspended Graphene Multilayers**

David Soler Delgado, YoungWoo Nam, DongKeun Ki, Alberto Morpurgo
Dep. of Quantum Matter Physics (DQMP) and Group of Applied Physics (GAP), University of Geneva

Suspended Bernal-stacked graphene multilayers exhibit a broken-symmetry ground state whose origin remains to be understood. Based on electrical transport measurements, we observe a second-order phase transition, whose critical temperature (T_c) increases a function of the thickness of the system, starting from 12 K in bilayer up to 100 K in heptalayer devices. Furthermore, by means of a phenomenological model, we attribute this transition to the incursion of a self-consistent valley- and spin-dependent staggered potential $\Delta(T)$ that changes sign from one layer to the next.
Our experimental observation of such finite-temperature phase transition imposes additional constraints to the any microscopic theory which attempts to describe electronic correlations on these multilayer graphene systems.

645 **Topological 0D Defect States in 3D Insulators**

Frank Schindler [1], Stepan S. Tsirkin [1], Titus Neupert [1], B. Andrei Bernevig [2], Benjamin J. Wieder [2]
[1] University of Zürich, [2] Princeton University

Crystal defects in topological insulators (TIs) are known to bind anomalous electronic states with two fewer dimensions than the bulk; the most commonly cited examples are the helical modes bound to screw dislocations in weak TIs. In this talk, we extend the classification of topological electronic defect states. By mapping the Hamiltonians of planes in momentum space to the real- space surfaces between screw or edge dislocations with integer Burgers vectors, we show that these crystalline defects can bind higher-order end states with fractional charge. We support our findings with extensive numerical calculations. Using density functional theory, we demonstrate the presence of first-order 0D defect states in PbTe monolayers, and HEND states in 3D SnTe crystals.

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Cavity-mediated fermionization of long-range interacting bosons

Paolo Molignini [1], Camille Lévêque [2], Hans Keßler [3], Ramasubramanian Chitra [1], Axel Lode [2]
[1] ETH Zürich, [2] Universität Wien & TU Wien, [3] Universität Hamburg

We investigate and compare few-particle one-dimensional bosonic and fermionic gases with infinite-range interactions induced by a laser-driven dissipative optical cavity by computing density distributions and correlation functions. With increasing cavity-atom coupling, both types of gases self-organize into a one-dimensional lattice structure with different site occupations. As the cavity-mediated light-matter interactions are increased further, the bosons progressively occupy the outer lattice sites and eventually completely localize into highly-correlated single-particle states. At this stage, the correlation functions and density fluctuations of the bosonic gas are indistinguishable from the fermionic ones. We comment on the interplay between contact and cavity-mediated interaction on the emergence of fermionization. Finally, we suggest experimental regimes where our theoretical findings could be tested.

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Tuning of the depolarization field, built-in voltage and nanodomain structure in ferroelectric thin films and heterostructures

Céline Lichtensteiger [1], Christian Weymann [1], Stéphanie Fernandez-Pena [2], Pavlo Zubko [3], Patrycja Paruch [1], Jean-Marc Triscone [1]
[1] DQMP - University of Geneva, [2] CERN,
[3] London Center for Nanotechnology and Department of Physics and Astronomy

Deterministic control of the intrinsic polarisation state of ferroelectric thin films is essential for devises applications. Additionally to the now well-established role of electrostatic boundary condition and epitaxial strain, we show also the importance of Pb-O divacancy gradients. We report on the full control of the polarisation orientation of ferroelectric thin films through changes in the growth temperature and electrical boundary conditions. Using piezo-force microscopy, x-ray diffraction and transmission electron microscopy, we investigated $PbTiO_3$ ultrathin films, $PbTiO_3$/$SrTiO_3$ superlattices and $PbTiO_3$-$SrTiO_3$ solid solution in thin film form, and showed how to fully control their intrinsic polarisation state by tuning the electrostatic boundary conditions and the divacancy dipole gradients.

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Weak Localization and Antilocalization in Nodal-Line Semimetals: Dimensionality and Topological Effects

Oded Zilberberg, ETH Zürich, Hai-Zhou Lu, ShenZhen, China, Wei Chen, Nanjing, China

Nodal-line semimetals offer a unique setting for novel transport phenomena. With weak disorder, the torus-shaped Fermi surface and encircled π Berry flux carried by the nodal loop generate a fascinating interplay between the effective dimensionality of electron diffusion and band topology, which depends on the scattering range of the impurity potential relative to the size of the nodal loop. For a short-range impurity potential, backscattering is dominated by the interference paths that do not encircle the nodal loop, yielding a 3D weak localization effect. In contrast, for long-ranged impurities, diffusion occurs in effective 2D planes and backscattering is dominated by interference paths that encircle the nodal loop, leading to weak antilocalization with a 2D scaling law.

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Structure-Property Relations in the $Ca_{1-x}Sr_xAlSi$ Solid Solution

Dorota Walicka [1], Jorge Lago [1,2], Fabian O. von Rohr [1]
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CaAlSi and SrAlSi are ternary superconductors that crystallize in AlB_2-type structures with critical temperatures of T_c = 8 K, and 5 K, respectively. They surprisingly differ in properties among each other although they have similar electronic structures, and only a small difference in their crystallographic structures. We have in a systematic approach analyzed the $Ca_{1-x}Sr_xAlSi$ solid solution and its evolution of the electronic and structural properties. We find that the superconductivity in this system is closely connected to the appearance of the structural distortion of the $[AlSi]_6^{2-}$ layers. Based on our results we establish the electronic phase diagram and compare it to the one of MgB_2.

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Superconductivity in the η-carbide-type oxides $Zr_4Rh_2O_x$

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We report on the synthesis and the superconductivity of the η-carbide type oxides $Zr_4Rh_2O_x$ (x = 0.7, 1.0). Detail physical measurements show that they are strongly type-II bulk superconductors with critical temperatures of $T_c \approx 2.8$ K and 4.7 K in the resistivity, respectively. Our results support that the η-carbide compounds are a versatile family of compounds for the investigation of the interplay of interstitial doping on physical properties in cage-structured compounds, especially for superconductivity.