Frontiers in Topological Quantum Matter
1-5 May 2017, NORDITA, Stockholm
Poster presentations

Disorder robustness and protection of Majorana bound states in ferromagnetic chains on conventional superconductors

Oladunjoye Awoga, Uppsala University

Majorana bound states (MBS) are well-established in the clean limit in wires of ferromagnetically aligned impurities deposited on conventional superconductors with finite spin-orbit coupling. Here we show that these MBS are very robust against disorder. By performing self-consistent calculations we find that the MBS are protected as long as the surrounding superconductor show no large signs of inhomogeneity. We find that longer wires offer more stability against disorder for the MBS, albeit the minigap decreases, as do increasing strengths of spin-orbit coupling and superconductivity.

Strongly angle-dependent magnetoresistance in Weyl semimetals with long-range disorder

Jan Behrends, MPI Physics of Complex Systems, Dresden

The chiral anomaly in Weyl semimetals states that the left- and right-handed Weyl fermions, constituting the low energy description, are not individually conserved, resulting, for example, in a negative magnetoresistance in such materials. Recent experiments see strong indications of such an anomalous resistance response; however, with a response that at strong fields is more sharply peaked for parallel magnetic and electric fields than expected from simple theoretical considerations. Here, we uncover a mechanism, arising from the interplay between the angle-dependent Landau level structure and long-range scalar disorder, that has the same phenomenology. In particular, we analytically show, and numerically confirm, that the internode scattering time decreases exponentially with the angle between the magnetic field and the Weyl node separation in the large field limit, while it is insensitive to this angle at weak magnetic fields. Since, in the simplest approximation, the internode scattering time is proportional to the anomaly-related conductivity, this feature may be related to the experimental observations of a sharply peaked magnetoresistance.

Topological band classification of point-nodal and line-nodal (semi-)metals

Adrien Bouhon, Uppsala University

We combine space group representation theory together with scanning of closed subdomains of the Brillouin zone with Wilson loops to algebraically determine global band structure topology. We show that the energy ordering of the irreducible representations at high-symmetry points fully determines the global band topology.

Emergent Weyl nodes and Fermi arcs in a Floquet Weyl semimetal

Leda Bucciantini, MPI Physics of Complex Systems, Dresden

When a Dirac semimetal is subject to a circularly polarized laser, it is predicted that the Dirac cone splits into two Weyl nodes and a non-equilibrium transient state called the Floquet Weyl semimetal is realized. We focus on the previously unexplored low frequency regime, where the upper and lower Dirac bands resonantly couples with each other through multi-photon processes, which is a realistic situation in solid state ultrafast pump-probe experiments. We find a series of new Weyl nodes emerging in pairs when the Floquet replica bands hybridize with each other. The nature of the Floquet Weyl semimetal with regard to the number, locations, and monopole charges of these Weyl nodes is highly tunable with the amplitude and frequency of the light. We derive an effective low energy theory using Brillouin-Wigner expansion and further regularise the theory on a cubic lattice. The monopole charges obtained from the low-energy Hamiltonian can be reconciled with the number of Fermi arcs on the lattice which we find numerically.

PT-invariant Weyl semimetals

Michele Burrello, University of Copenhagen

Weyl semimetals typically appear in systems in which either time-reversal (T) or inversion (P) symmetry is broken. Here we show that these are not the only possibilities: in the presence of gauge potentials this topological state of matter can also arise in fermionic lattices preserving both T and P. The paradigmatic case is a cubic lattice model with π-fluxes, a model which is invariant under a physical PT transformation and is realizable with ultracold fermions trapped in optical lattices. In this system, gauge symmetries play a fundamental role in the formation of Weyl points, and it is necessary to introduce a distinction between canonical and physical T and P symmetries. This PT invariant Weyl phase is stable against the main perturbations which may characterize its ultracold atom realizations, as, for example, the introduction of a trapping potential. Also the presence of random perturbations of the (artificial) magnetic fluxes do not destroy this phase for finite size systems under realistic assumptions and can be compared to a local disorder in solid state scenarios. Finally, the construction of PT-invariant Weyl semimetal can be extended to systems with a U(2) gauge potentials, thus including both magnetic fluxes and a spin-orbit coupling. When the non-Abelian potential is turned on, due to the presence of a discrete rotation symmetry, the Weyl points assume a quadratic dispersion along two directions and constitute double monopoles for the Berry curvature.

Robust and multiply charged nodes in centrosymmetric systems

Tomáš Bzdušek, ETH Zürich

Weyl points in three spatial dimensions are characterized by a $\mathbb{Z}$-valued charge – the Chern number – which makes them stable against a wide range of perturbations. A set of Weyl points can mutually annihilate only if their net charge vanishes, a property we refer to as "robustness". While nodal loops are usually not robust in this sense, Ref. [1] found that those appearing in systems with spatial inversion and time-reversal without spin-orbit interaction develop a Z_2 charge analogous to the Chern number of Weyl points. Nodal loops carrying a non-trivial value of this charge are robust, i.e. they can be gapped out only by pairwise annihilation and not on their own. As this is an additional charge independent of the Berry π-phase flowing along the band degeneracy, such nodal loops are also doubly charged. We remark that no additional crystalline symmetries beyond the spatial inversion are necessary for the appearance and protection of such nodes.

In the presented work [2], we show how the observation of robust and multiply charged nodes in Ref. [1] generalizes to centrosymmetric extension of all Atland-Zirnbauer classes of arbitrary spatial dimension. We discuss the meaning of the additional charge for all non-trivial instances in three spatial dimensions, and discuss how the identified robust nodes relate to various semimetallic and superconducting phases.

[1] C. Fang, Y. Chen, H.-Y. Kee, and L. Fu, *Phys. Rev. B* **92**, 081201(R) (2015)

[2] T. Bzdušek and M. Sigrist (in preparation)

First-principles studies of transition-metal magnetic impurities in Sb_2Te_3 topological insulator

Carlo Canali, Linnaeus University

The interplay between the conducting Dirac surface states and the magnetization degree of freedom in a magnetic topological insulator (TI) is crucial for future applications in spintronics and for the realization of novel quantum phenomena such as the quantum anomalous Hall effect (QAHE). Despite experimental progress in measuring the signatures of the QAHE in thin films of magnetically-doped TIs, the fate of the topological surface states, i.e. the presence or absence of a gap upon magnetic doping [1] as well as the nature of magnetic interactions in these systems [2] are still under debate. Motivated by on-going experiments, we have systematically investigated the electronic structure and the magnetic properties of transition-metal doped Sb_2Te_3 for both bulk and surface doping, using first-principles calculations based on density functional theory. In addition to a magnetization-dependent gap, magnetic dopants introduce impurity states in the bulk gap, whose detailed electronic and magnetic structure depends on the specific character of the dopant as well as on the correlation between the d electrons of the magnetic dopant. We investigate in particular the relationship between the bulk and the surface magnetic anisotropy, and show that the anisotropy has a complex behavior as a function of magnetic doping, which needs to be thoroughly characterized to identify the conditions for the realization of a robust QAHE.

[1] Sessi et al., Nat. Comm. 7, 12027 (2016)

[2] Grauer et al., Phys. Rev. B 92, 201304 (2015).

Trial wave functions for a Composite Fermi liquid on a torus

Mikael Fremling, Maynooth University

We study the two-dimensional electron gas in a magnetic field at filling fraction $\nu = 1/2$. At this filling the system is in a gapless state which can be interpreted as a Fermi liquid of composite fermions. We construct trial wave functions for the system on a torus, based on this idea, and numerically compare these to exact wave functions for small systems found by exact diagonalization. We find that the trial wave functions give an excellent description of the ground state of the system, as well as its charged excitations, in all momentum sectors. We analyse the dispersion of the composite fermions and the Berry phase associated with dragging a single fermion wave function around the Fermi surface and comment on the implications of our results for the current debate on whether composite fermions are Dirac fermions.

Ultrafast cooling and heating scenarios for laser-induced phase transition in CuO

J. Hellsvik, NORDITA

We report theoretical modeling of the sub-picosecond magnetic phase transition which recently has been experimentally observed in optically pumped samples of multiferroic CuO [1]. Intriguingly, different excitation mechanisms are found to drive distinct dynamics. Similar as in experiments and independently of the excitation mechanism, our multi-scale modeling [2,3,4] shows that laser excitation of CuO can drive the spin system from the collinear ground state to the incommensurate multiferroic phase on a picosecond time scale. However, depending on the excitation mechanism, the transition proceeds either by heating up the spin system or by cooling it down, where the latter is a manifestation of an ultrafast magneto-caloric effect [4]. In analogue with the ultrafast dynamics observed in ferrimagnetic rare-earth transition metal alloys, it is found that the time-scale of the observed dynamics is determined mainly by the strength of the exchange interactions [5].

[1] S. L. Johnson *et al*., Phys. Rev. Lett. **108**, 037203 (2012).
[2] *Atomistic spin-dynamics foundations and applications*, O. Eriksson, A. Bergman, L. Bergqvist, and J. Hellsvik (Oxford University Press, 2017).
[3] J. Hellsvik *et al*., Physical Review B **90**, 014437 (2014).
[4] J. Hellsvik, J. H. Mentink, and J. Lorenzana, Physical Review B **94**, 144435 (2016).
[5] J. H. Mentink, J. Hellsvik *et al*., Phys. Rev. Lett **108**, 037203 (2012).

Bipartite charge fluctuations as indicators of topological phase transitions in 1 and 2 dimensions

Loïc Herviou, Ecole Polytechnique

Bipartite charge fluctuations (BCF) have been introduced to provide an experimental indication of many-body entanglement. They have proved themselves to be a very efficient and useful tool to characterize quantum phase transitions in a variety of quantum models conserving the total number of particles (or magnetization for spin systems). We present results on the BCF in generic BDI one-dimensional topological models and two dimensional Dirac materials. The considered charge (either the fermionic number or a pseudo-spin polarization) is no longer conserved, leading to macroscopic fluctuations of the number of particles. We demonstrate that at phase transitions characterized by a linear dispersion, the BCF probe the change in a winding number that allows one to pinpoint the transition and corresponds to the topological invariant for standard models. Additionally, we prove that a sub-dominant logarithmic contribution is still present at the exact critical point. Its quantized coefficient is universal and characterizes the critical model.

Majorana fermions from pseudo-scalar superconductivity in Dirac materials

S. A. Jafari, University of Duisburg-Essen

We examine the most general form of superconductivity that can be induced into a three dimensional Dirac material that can be classified as scalar, pseudo-scalar, vector, pseudo-vector and tensor. We find that only the pseudo scalar pairing is able to provide a topological superconductor in the DIII class. The origin of gap closing in this system is the competition between a singlet superconducting pairing that breaks a chiral symmetry and the Dirac mass.

Chiral anomaly and negative longitudinal magnetoresistance in Weyl semimetals within a Boltzmann approach

Annika Johansson, MPI Microstructure Physics, Halle

In Weyl semimetals, the application of non-orthogonal electric and magnetic fields leads to the chiral anomaly. The breaking of the chiral symmetry results in nonconservation of chiral charge [1-3]. Transport phenomena related to the chiral anomaly are the anomalous Hall effect, the chiral magnetic effect, and the appearance of a negative longitudinal magnetoresistance.

We consider the chiral anomaly in Weyl semimetals for small magnetic fields [4].

Using a semiclassical Boltzmann approach, we investigate the additional contribution to the longitudinal charge conductivity related to the chiral anomaly. The longitudinal magnetoresistance is calculated for model systems [5] including anisotropic and energy dependent momentum relaxation times. The energy dependence of the scattering processes has a pronounced effect on the transport properties, whereas the influence of the relaxation time anisotropy is negligible.

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[2] J. S. Bell and R. Jackiw, Nuovo Cimento A 60, 47 (1969)
[3] H. B. Nielsen and M. Ninomiya, Phys. Lett. B 130, 389 (1983)
[4] D. T. Son and B. Z. Spivak, Phys. Rev. B 88, 104412 (2013)
[5] S. Murakami and S. Kuga, Phys. Rev. B 78, 165313 (2008); R. Okugawa and S. Murakami, Phys. Rev. B 89, 235315 (2014)

Controlling topological superconductivity by magnetization dynamics

Vardan Kaladzhyan, IPhT Saclay/LPS Orsay

We study theoretically a chain of precessing classical magnetic impurities in an s-wave superconductor. Utilizing a rotating wave description, we derive an effective Hamiltonian that describes the emergent Shiba band. We find that this Hamiltonian shows non-trivial topological properties, and we obtain the corresponding topological phase diagrams both numerically and analytically. We show that changing precession frequency offers a control over topological phase transitions and the emergence of Majorana bound states. Our proposal could be implemented by driving electrically the magnetic impurities or magnetic texture with microwave radiation, by means of spin-transfer torque, or using spin superfluidity in the case of planar magnetic order.

Odd-frequency superconductivity in Sr_2RuO_4 measured by Kerr rotation

Lucia Komendova, Uppsala University

We establish the existence of bulk odd-frequency superconductivity in Sr_2RuO_4 and show that an intrinsic Kerr effect is a direct evidence of this state. We use both general two- and three-orbital models, as well as a realistic tight-binding description of Sr_2RuO_4 to demonstrate that odd-frequency pairing arises due to finite hybridization between different orbitals in the normal state, and is further enhanced by finite inter-orbital pairing. Reference: arXiv:1702.03181.

Anatomy of Topological Flat and Surface States: Exact Solutions from Destructive Interference on Frustrated Lattices

Flore Kunst, Stockholm University

The main feature of topological phases is the presence of robust boundary states, which appear for example in the form of chiral edge states in Chern insulators and open Fermi arcs on the surfaces of Weyl semimetals. Even though, non-interacting, topological systems can be straightforwardly described in fully periodic systems, the understanding of the corresponding boundary states has almost exclusively relied on numerical studies. In our work, we present a general method on how to find exact, analytical solutions for topological as well as trivial boundary states using a generic tight-binding model on a large class of geometrically frustrated lattices without the necessity of having to fine-tune hopping amplitudes. Our method is inspired by a similar approach that has been used in the past to construct, topologically-trivial, flat band models from local constraints on 'line graphs', in which case fine-tuning is required in the sense that hopping is strictly local. We expand on this work by considering a larger class of lattices, finding solutions for both topologically trivial and non-trivial bands, and going beyond the need for fine-tuning. In this sense, it is likely that our work will contribute to both the research fields of flat-band physics and that of topological matter, as well as advance the cross-fertilization between them. In my poster, I present a number of examples to illustrate our discoveries, some of which are experimentally relevant such as the derivation of exact solutions for Fermi arcs in the recently synthesized slabs of pyrochlore iridates. The publication can be found under arXiv: 1703.04628.

Lattice Genons

Zhao Liu, Free University of Berlin

We investigate extrinsic wormhole-like defects that effectively increase the genus of space in lattice versions of multi-component fractional quantum Hall systems. Although the original band structure is distorted by these defects, leading to localized midgap states, we find that a new lowest flat band representing a higher genus system can be engineered by tuning local single-particle potentials. Remarkably, once local many-body interactions in this new band are switched on, we identify various Abelian and non-Abelian fractional quantum Hall states, whose ground-state degeneracy increases with the number of defects, i.e, with the genus of space. This sensitivity of topological degeneracy to defects provides a "proof of concept" demonstration that genons, predicted by topological field theory as exotic non-Abelian defects tied to a varying topology of space, do exist in realistic microscopic models. Specifically, our results indicate that genons can be created in the laboratory by combining the physics of artificial gauge fields in cold atom systems with already existing holographic beam shaping methods for creating wormhole-like defects.

Impurity bound states in d-wave superconductors with subdominant order parameters

Mahdi Mashkoori, Uppsala University

It is well-known that a single magnetic impurity induces bound states inside the energy gap of conventional s-wave superconductors. On the other hand, in d-wave superconductors only virtual bound states with finite lifetime can be induced by both potential and magnetic impurities. However, in small islands of $YBa_2Cu_3O_{7-\delta}$ a fully gapped spectrum has recently been discovered [1, 2] and this fact paves the way to induce real bound states in d-wave superconductors. In this work, we investigate the intra-gap bound states due to potential and magnetic impurities in the two candidate fully gapped states for this system: the topologically trivial d + is-wave state and the topologically non-trivial d + id'-wave, or chiral d-wave state. Using both the analytic T-matrix formalism and self-consistent numerical tight-binding lattice calculations, we show that potential and magnetic impurities create entirely different intra-gap bound states in d + is-wave and chiral d-wave superconductors, despite both being fully gapped and with a parent $d_{x^2-y^2}$ gap. Therefore, our results suggest that the bound states are mainly dependent on the subdominant order parameter. Considering that recent experiments have demonstrated an access to adjustable coupling J [3], magnetic impurities thus offer an intriguing way to clearly distinguish between the chiral d-wave state and the likewise time-reversal symmetry breaking but topologically trivial d + is-wave state.

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Conformal QED in two-dimensional topological insulators

Natália Menezes, Utrecht University

It has been shown recently that local four-fermion interactions on the edges of two-dimensional time-reversal-invariant topological insulators give rise to a new non-Fermi-liquid phase, called helical Luttinger liquid (HLL). In this work, we provide a first-principle derivation of this non-Fermi-liquid phase based on the gauge-theory approach. We start by considering massless Dirac fermions interacting through a quantum dynamical electromagnetic field. These fermions are confined on the one-dimensional boundary of the topological insulator, whereas the (virtual) photons of the U(1) gauge field are free to propagate in all the three spatial dimensions that represent the physical space where the material is embedded. Within these assumptions, through a dimensional-reduction procedure, we derive the effective 1+1-dimensional interacting fermionic theory described both by a massless Thirring model plus a non-local interaction. The bosonized Thirring Hamiltonian describes exactly a HLL with a parameter K and a renormalized Fermi velocity that depend on the value of the fine-structure constant.

Thermal transport in Weyl semimetals: links to the axial-gravitational anomaly, and vortex bound states

Tobias Meng, Dresden University

In my poster, I discuss two examples that illustrate the importance of thermal transport measurements in Weyl systems. On the one hand, I will show that thermal transport in Weyl semimetals is related to gravitational physics, and in particular provides experimental evidence for the existence of the mixed axial-gravitational anomaly [1]. On the other hand, thermal transport along vortices in inversion-symmetry breaking Weyl systems with superconductivity provides a fingerprint for the underlying Weyl-ness of these fully gapped systems.

[1] "Experimental signatures of the mixed axial-gravitational anomaly in the Weyl semimetal NbP", J. Gooth, A. C. Niemann, T. Meng, A. G. Grushin, K. Landsteiner, B. Gotsmann, F. Menges, M. Schmidt, C. Shekhar, V. Süß, R. Hühne, B. Rellinghaus, C. Felser, B. Yan, and K. Nielsch, arXiv:1703.10682.

Topological order, symmetry, and Hall response of two-dimensional spin-singlet superconductors

Sergey Moroz, TU Munich

Fully gapped two-dimensional superconductors coupled to dynamical electromagnetism are known to exhibit topological order. Although for an s-wave paired state its topological properties can be well captured by the toric code model, I will demonstrate that in the presence of global symmetries this picture is incomplete. In this poster I will present a unified low-energy description for spin-singlet paired states by deriving topological Chern-Simons field theories for s-wave, d + id, and chiral higher even-wave superconductors. These theories encode the quantum statistics and fusion rules of Bogoliubov quasiparticles and vortices and incorporate global continuous symmetries - specifically, spin rotation and conservation of magnetic flux - present in all singlet superconductors, which firmly establishes superconductors as symmetry enriched topological phases. I will also discuss the Hall responses for these symmetries and the physics at the edge.

Highly tunable time-reversal-invariant topological superconductivity in topological insulator thin films

Fariborz Parhizgar, NORDITA

We investigate extrinsic wormhole-like defects that effectively increase the genus of space in lattice versions of multi-component fractional quantum Hall systems. Although the original band structure is distorted by these defects, leading to localized midgap states, we find that a new lowest flat band representing a higher genus system can be engineered by tuning local single-particle potentials. Remarkably, once local many-body interactions in this new band are switched on, we identify various Abelian and non-Abelian fractional quantum Hall states, whose ground-state degeneracy increases with the number of defects, i.e, with the genus of space. This sensitivity of topological degeneracy to defects provides a "proof of concept" demonstration that genons, predicted by topological field theory as exotic non-Abelian defects tied to a varying topology of space, do exist in realistic microscopic models. Specifically, our results indicate that genons can be created in the laboratory by combining the physics of artificial gauge fields in cold atom systems with already existing holographic beam shaping methods for creating wormhole-like defects.

Topological staggered-field-electric effect with bipartite magnets

Stefan Rex, NTNU Trondheim

When the surface of a topological insulator (TI) is exposed to an orthogonal magnetization, the Dirac surface states acquire a mass such that an energy gap opens up in the surface spectrum. For this state, a

topological magnetoelectric effect (TME) has been derived theoretically, whereby an electric field applied at the surface induces a parallel magnetic polarization.
We study this effect at the interface of a TI with a bipartite magnetic insulator, where the TME occurs for the two magnetizations associated with the two sublattices. We find that within a certain range of parameters the TME acts in the opposite direction on the two sublattices. An applied electric field will then evoke a staggered field rather than a net magnetization. An important requirement for this staggered-field-electric effect is that the magnetic moments on the two sublattices have a different magnitude, as in ferrimagnets. Ferrimagnets and ferromagnets can thus behave very differently when used in heterostructures with TIs.

Quantitative analytical theory for disordered nodal points

Björn Sbierski, Free University of Berlin

Disorder effects are especially pronounced around nodal points in linearly dispersing bandstructures as present in graphene or Weyl semimetals. Despite the enormous experimental and numerical progress, even a simple quantity like the average density of states cannot be assessed quantitatively by analytical means. We demonstrate how this important problem can be solved employing the functional renormalization group method and, for the two dimensional case, demonstrate excellent agreement with reference data from numerical simulations based on tight-binding models. In three dimensions our analytic results also improve drastically on existing approaches.

Superconductivity in the Harmonic Honeycombs

Johann Schmidt, Uppsala University

Recent experimental discoveries have opened the door for a series of 3D lattice structures, called the Harmonic Honeycombs. Starting from close relatives of the 2D honeycombs, we have studied superconductivity down to the simplest members of the series, the so-called Hyper- and Stripyhoneycomb. We can show that well-known results from the 2D case can be applied to many members of the series, and discuss how understanding the symmetry of the Hyper- and Stripyhoneycomb allows us to bridge the gap to the 2D case.

Disordered tilted Weyl cones: a renormalization group perspective

Tycho Sikkenk, Utrecht University

Weyl semi-metals (WSMs) are characterised by a non-degenerate band touching point in their dispersion where the density of states vanishes and the spectrum is approximately linear. This cone-like behaviour strongly affects the reaction of these materials to disorder, most notably resulting in a critical strength below which the RG flow is towards weak disorder. In a less idealised case the cones in the dispersion might be tilted away from their canonical upright position. We investigate the critical strength for these tilted WSMs, and show tilting implies they become less semi and more metallic.

Equivalence between an s-wave topological polarized Fermi superfluid with spin-orbit coupling and the BHZ model

Lauri Toikka, Massey University

We have shown that the relevant low-energy excitations of a population-imbalanced topological s-wave Fermi superfluid with spin-orbit coupling can be understood in terms of the Bernevig-Hughes-Zhang (BHZ) model. In particular, our results are a promising way to obtain the low-energy quasi-particle modes of the BEC-BCS crossover Fermi gas in the topological regime by solving an easier set of decoupled equations thus lowering the need for computational complexity. The mapping to the BHZ model is a powerful approach to directly understand the nature of the topological phase transition in the ultra-cold Fermi gas.

Zeeman and spin-orbit coupling effects in the electromagnetic response of nanowire Josephson junctions

Jukka Vayrynen, Yale University

We study the energy spectrum and the electromagnetic response of Andreev bound states in short Josephson junctions made of semiconducting nanowires. We focus on the joint effect of Zeeman and spin-orbit coupling on the Andreev level spectra. Our model incorporates the penetration of the magnetic field in the proximitized wires, which substantially modifies the spectra. We pay special attention to the occurrence of fermion parity switches at increasing values of the field. Our calculations can be used to extract quantitative information from microwave and tunneling spectroscopy experiments.

Room-temperature nanosecond spin relaxation in few-layer WTe_2 and $MoTe_2$

Qisheng Wang, National University of Singapore

The Weyl semimetal[1,2] WTe_2 and $MoTe_2$ are promising to generate large charge-to-spin current conversion as they possess topologically-protected spin-polarized states[3,4] and can carry the tremendous current density[5]. Further, the intrinsic noncentrosymmetry of WTe_2 and $MoTe_2$ induces a unique property of crystal symmetry-controlled spin-orbit torques.[6] An important question to be answered for developing spintronic devices is how spins relax in WTe_2 and $MoTe_2$. Here, we observe an extremely long spin lifetime (1.2 ns) at room-temperature in chemical vapor deposition (CVD)-grown WTe_2 and $MoTe_2$ thin films using time-resolved Kerr rotation (TRKR) spectroscopy, which is three orders of magnitude longer than GaAs and Bi_2Se_3 (a 3D topological insulator). Supported by transient reflectivity spectroscopy and *ab initio* calculation, we identify a mechanism of long-lived spin polarization resulting from a slow phonon-assisted recombination of electron-hole pairs, and suppression of backscattering required by time-reversal and lattice symmetry operation. In addition, we find the spin polarization is firmly pinned along the strong internal out-of-plane magnetic field (~346 T) induced by the large spin splitting (~40 meV). Our work provides an insight into the physical origin of long-lived spin polarization in Weyl semimetals which could be used to transport spins in a long distance or manipulate spins for a long time at room temperature.

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MacNeill, D., Stiehl, G. M., Guimaraes, M. H. D., Buhrman, R. A., Park, J., Ralph, D. C., Control of spin-orbit torques through crystal symmetry in WTe_2/ferromagnet bilayers. *Nature Phys.* Doi:10.1038/nphys3933 (2016).

Topological Dirac Insulators

Benjamin Wieder, Princeton University

Recent developments in the relationship between bulk topology and surface crystalline symmetries have led to the discovery of materials whose gapless surface states are protected by crystal symmetries, such as mirror topological crystalline insulators and nonsymmorphic hourglass fermion insulators. In fact, there exists only a very limited set of possible surface crystal symmetries, captured by the 17 ``wallpaper groups.'' Here, we show that all possible crystalline insulators, symmorphic and nonsymmorphic, can be exhaustively characterized by considering these wallpaper groups. In particular, the two wallpaper groups with multiple glide lines, pgg and p4g, allow for a new topological insulating phase, whose surface spectrum consists of only a single, fourfold-degenerate, true Dirac fermion. Like the surface state of a conventional topological insulator, the surface Dirac fermion in this ``topological Dirac insulator'' provides a theoretical exception to a fermion doubling theorem. Unlike the surface state of a conventional topological insulator, it can be gapped into topologically distinct surface regions while keeping time-reversal symmetry, allowing for networks of topological surface quantum spin Hall domain walls. We report the theoretical discovery of new topological crystalline phases in the A$_2$B$_3$ family of materials in space group 127, finding that Sr$_2$Pb$_3$ hosts this new topological surface Dirac fermion. Furthermore, (100)-strained Au$_2$Y$_3$ and Hg$_2$Sr$_3$ host related topological surface hourglass fermions. We also report the presence of this new topological hourglass phase in Ba$_5$In$_2$Sb$_6$ in space group 55. For orthorhombic space groups with two perpendicular glides, we catalog all possible bulk topological phases by a consideration of the allowed non-abelian Wilson loop connectivities, and provide topological invariants to distinguish them.

Effect of disordered geometry on transport properties of three dimensional topological insulator nanowires

Emmanouil Xypakis, MPI Physics of Complex Systems, Dresden

Three dimensional topological insulator nanowires are materials which, while insulating in the bulk, have a metallic boundary described by a two dimensional Dirac Hamiltonian with antiperiodic boundary conditions. Transport properties of this system have been extensively studied in the limit where the surface manifold is conformally flat (e.g., a cylinder) in the presence of a random disordered scalar potential. In this poster I will present how this picture is altered when a more realistic surface manifold is chosen, such as a cylinder with a randomly fluctuating radius.

Superconductivity in Weyl metals

Alexander Zyuzin, KTH

We report on a study of intrinsic superconductivity in a doped Weyl semimetal with tilted Weyl cones. We find that, in an inversion-symmetric Weyl metal, the odd-parity BCS state has a lower energy than the FFLO state, despite the nodes in the gap. The FFLO state, on the other hand, may have a lower energy in a noncentrosymmetric Weyl metal, in which Weyl nodes of opposite chirality have different energy. However, realizing the FFLO state is, in general, very difficult since the paired states are not related by any exact symmetry, which precludes a weak-coupling superconducting instability. We also discuss some of the physical properties of the nodal BCS state, in particular, Majorana and Fermi arc surface states.