IBS-APCTP Conference on

Advances in the Physics of Topological & Correlated Matter

September 19 Mon - 23 Fri, 2022
IBS Science Culture Center,
Daejeon Korea

Program Book

Institute for Basic Science

apctp
asia pacific center for theoretical physics

IBS-APCTP Conference on

Advances in The Physics of Topological and Correlated Matter

Topology plays a pivotal role at the forefront in understanding correlated quantum matter.

A plethora of relevant fields, e.g. topological superconductivity and magnetism, fractional Hall effect and spin liquids, non-equilibrium and open quantum systems, turn into exciting platforms to test our insights and to find new exotic states of matter. The main goal of this IBS-APCTP conference is to bring together experts from the above fields to get an overview of the current state and the most recent advances in understanding topological and correlated quantum matter.

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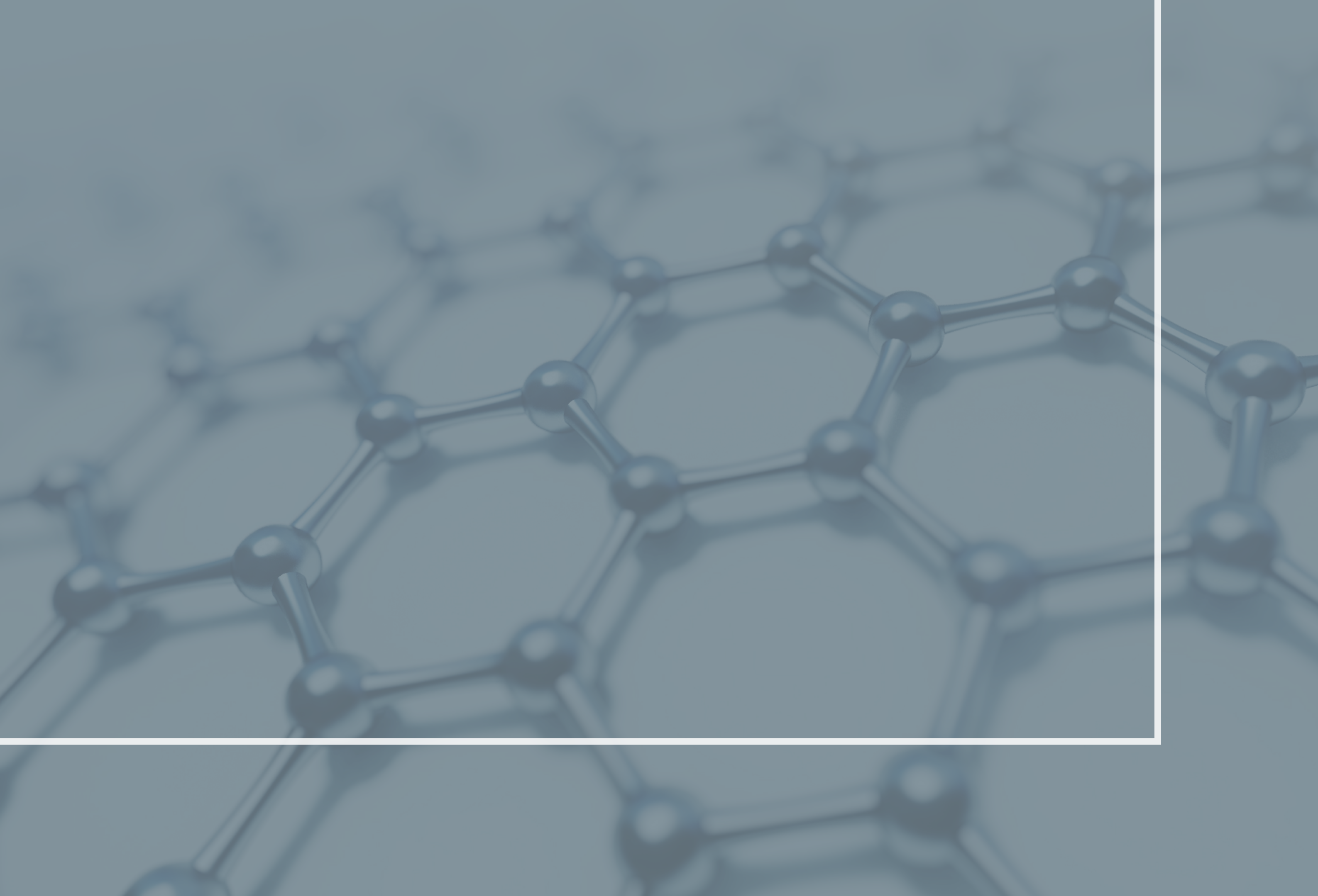
Frequently Asked Questions & Information



Frequently Asked Questions & Information

VISITOR PROGRAM

In case of emergency: +82 10 2743 4200 (Ms. Gileun Lee)

ACCOMMODATION, MEALS, TRAVEL

– Good Morning Residence Hotel Hue provides breakfast (7 – 9 am)
– IBS cafeteria (1st floor): lunches on Mon. – Fri.
(please use the provided coupons, see the menu in the arrival folder)
– Shuttle bus departure times (sharp):
to the IBS: 9:50 am (Mon.), 8.20 am (Tue. - Fri.)
to the hotel: 7.30 pm (Mon.), 8 pm (Tue., Thu.), 8 30 pm (Wed.), 4:30 pm (Fri.)

SOCIAL PROGRAM

– Welcome reception (Monday, September 19)
Time: 5.30 pm, venue: IBS Science Culture Center, 3F
– Poster session (Tuesday, September 20 and Thursday, September 22)
Time: 5.30 pm, venue: IBS Science Culture Center, 3F
– Conference picture (Tuesday, September 21)
Time: 12.30 pm, meeting point: IBS Science Culture Center, 2F, Auditorium
– Excursion (Wednesday, September 21)
Departure: 1.30 pm, venue: Jeonju
Shuttle bus to the excursion: 1.30 pm (sharp) in front of IBS Science Culture Center
– Conference banquet (Wednesday, September 21)
Time: 7 pm, venue: 쌍촌본가 (Daejeon, Yuseong-gu, Wonchon-dong, 77-4)

ADDITIONAL INFORMATION – please contact pcs@ibs.re.kr

FEEDBACK FORM

Please scan the QR code with your phone camera to provide feedback on this conference.

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Program

Program

[DAY1] MONDAY, 19 SEPTEMBER		
10:00 – 10:40 (KST)	Registration	
10:40 – 11:00 (KST)	Opening Remarks	
11:00 – 12:30 (KST)	Chairperson : Sergej Flach	
	Changyoung Kim	Unusually Large Anomalous Hall Conductivity in CoS2 and Its Origin
	Masatoshi Sato	Bulk-Boundary Correspondence in Point-Gap Topological Phases
12:30 – 14:00 (KST)	Lunch	
14:00 – 15:30 (KST)	Chairperson: Daniel Leykam	
	Takashi Oka	Floquet Engineering and Topological Nonlinear Optics
	Gil-Ho Lee	Steady Floquet–Andreev States in Graphene Josephson Junctions
15:30 – 16:00 (KST)	Discussions & Coffee Break	
16:00 – 17:30 (KST)	Chairperson: Daniel Leykam	
	Andrew Pierce	Local Thermodynamic Measurements of Topological States in Magic Angle Graphene
	Robert-Jan Slager Online	Geometry and Multi-Gap States
17:30 – 19:30 (KST)	Welcome Reception	

Program

Time	[DAY2] TUESDAY, 20 SEPTEMBER		[DAY3] WEDNESDAY, 21 SEPTEMBER	
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	Philip Kim Online	Induced Superconductivity in the Fractional Quantum Hall Edge in Graphene Heterostructures	Haruki Watanabe	Topological Material Search via Symmetry Indicator and Filling Anomaly
	Riccardo Comin Online	Electronic Topology and Correlations in Kagome Metals	Charles Tschirhart / Andrea Young Online	Electrical Switching of Magnetic Order in Intrinsic Chern Insulators
10:30 – 11:00 (KST)	Discussions & Coffee Break			
11:00 – 12:30 (KST)	Chairperson: Ki-Seok Kim		Chairperson: Bohm-Jung Yang	
	Frank Pollmann Online	Quotient Symmetry Protected Topological Phenomena and Quantum Criticality	Franco Nori Online	Topological Non-Hermitian Origin of Surface Maxwell Waves
	Aris Alexandradinata	A Topological Principle for Photovoltaics	Daniel Leykam	Persistent Homology Analysis of Phase Transitions
12:30 – 14:00 (KST)	Lunch			
14:00 – 15:30 (KST)	Chairperson: Gil Young Cho			
	Jun Sung Kim	Large Magnetotransport Responses of Topological Van Der Waals Magnets		
	Benjamin Wieder	Spin-Resolved Topology, Partial Axion Angles, and Half Quantum Spin Hall Surface States in Higher-Order Topological Crystalline Insulators		
15:30 – 16:00 (KST)	Discussions & Coffee Break		Excursion	
16:00 – 17:30 (KST)	Chairperson: Gil Young Cho			
	Emil J. Bergholtz Online	Quantum Geometry and Fractional Chern Insulators in Moiré Materials		
	Mathias S. Scheurer Online	Zero-Field Superconducting Diode Effect in Twisted Trilayer Graphene		
17:30 – 18:30 (KST)	Poster Session			
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Time	[DAY4] THURSDAY, 22 SEPTEMBER		[DAY 5] FRIDAY, 23 SEPTEMBER	
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	Joseph George Checkelsky Online	Natural Superlattice Design of Quantum Materials	Eun-Ah Kim Online	Machine Learning Quantum Emergence
	Dam T. Son Online	Nonlinear Bosonization of Fermi Surfaces: The Method of Coadjoint Orbits	Nuh Gedik Online	Ultrafast Charge Order Dynamics in a Kagome Metal
10:30 – 11:00 (KST)	Discussions & Coffee Break			
11:00 – 12:30 (KST)	Chairperson: Aris Alexandradinata		Chairperson: Moon Jip Park	
	Moon Jip Park	Twisted Bilayer Magnets CrI3	Zhong Wang Online	Recent Progress in Non-Hermitian Physics beyond One Dimension
	Jeongwan Haah Online	Topological Phases of Discrete Unitary Dynamics	Chen Fang Online	The Topological Origin of Non-Hermitian Skin Effect
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	Ryo Hanai	Non-Reciprocal Frustration: Time Crystalline Order-by-Disorder Phenomenon and a Spin-Glass-like State	Roderich Moessner Online	Dynamical Fractal and Anomalous Noise in Clean Magnetic Crystal
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	Binghai Yan Online	Chirality-Driven Electronic Topology in DNA-Type Chiral Materials		
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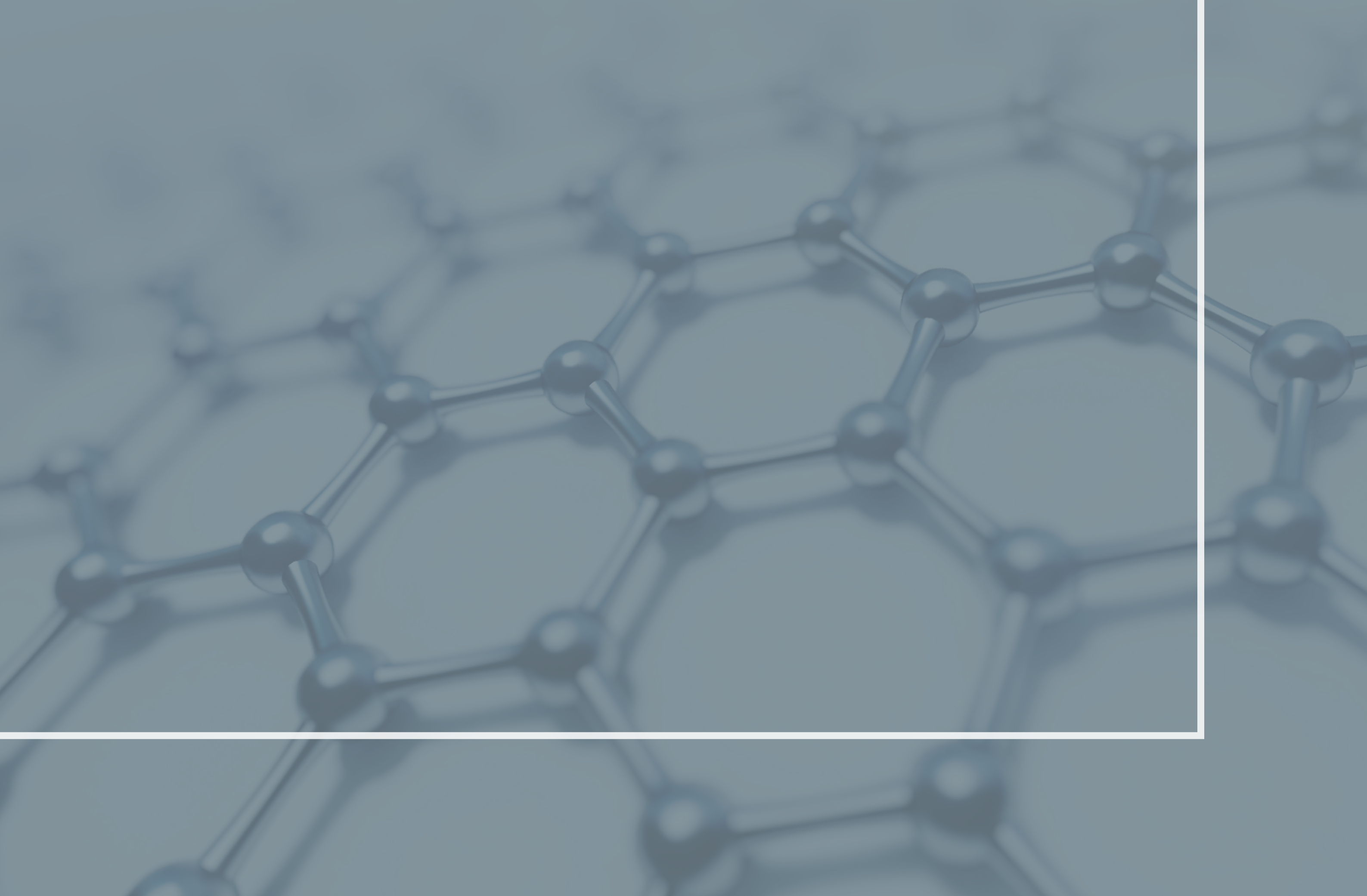
Abstracts



Unusually Large Anomalous Hall Conductivity in CoS2 and Its Origin

Changyoung Kim
IBS-CCES, SNU, Korea

(TBA)

Bulk-Boundary Correspondence in Point-Gap Topological Phases

Masatoshi Sato
YITP, Kyoto University, Japan

A striking feature of non-Hermitian systems is the presence of two different types of topology. One generalizes Hermitian topological phases, and the other is intrinsic to non-Hermitian systems, which are called line-gap topology and point-gap topology, respectively. Whereas the bulk-boundary correspondence is a fundamental principle in the former topology, its role in the latter has not been clear yet. In this talk, I discuss the bulk-boundary correspondence in the point-gap topology in non-Hermitian systems. After revealing the requirement for point-gap topology in the open boundary conditions, we clarify that the bulk point-gap topology in open boundary conditions can be different from that in periodic boundary conditions. We give a complete classification of the open boundary point-gap topology with symmetry and show that the non-trivial open boundary topology results in robust and exotic surface states[1].

[1] D. Nakamura, T. Bessho, M. Sato, arXiv:2205.15635

Floquet Engineering and Topological Nonlinear Optics

Takashi Oka
ISSP, U-Tokyo, Japan

Geometric effects in non-equilibrium systems driven by external fields are currently being studied very actively.

Dirac electrons driven by a laser electric field can be studied experimentally and theoretically, making it an ideal system for investigating unknown non-equilibrium phenomena.

In this talk, I will explain phenomena such as Floquet-Weyl semimetals, and geometric effects in quantum tunneling (twisted Landau-Zener tunneling) and their outcomes.

Steady Floquet-Andreev States in Graphene Josephson Junctions

Gil-Ho Lee
Department of Physics, POSTECH, Pohang 37673, South Korea

Engineering quantum states through light-matter interaction has created a new paradigm in condensed matter physics. A representative example is the Floquet-Bloch state, which is generated by time-periodically driving the Bloch wavefunctions in crystals. Previous attempts to realise such states in condensed matter systems have been limited by the transient nature of the Floquet states produced by optical pulses, which masks the universal properties of non-equilibrium physics. I will introduce our recent effort on the generation of steady Floquet Andreev (F-A) states in graphene Josephson junctions by continuous microwave application and direct measurement of their spectra by superconducting tunnelling spectroscopy [1]. We present quantitative analysis of the spectral characteristics of the F-A states while varying the phase difference of superconductors, temperature, microwave frequency and power. We hope that this study can provide a basis for understanding and engineering non-equilibrium quantum states in dissipative condensed matter systems.

[1] S. Park et al., Nature 603, 421–426 (2022).

Local Thermodynamic Measurements of Topological States in Magic Angle Graphene

Andrew Pierce
Harvard University

The discovery of superconductivity and other correlated phases in magic-angle twisted trilayer graphene has provided an intriguing example of a moiré system in which complex many-body physics arises from flat bands coupled to dispersive bands. However, the microscopic thermodynamic properties of these phases, as well as the nature of the interactions between the “heavy” and “light” fermions in the system, have thus far remained difficult to access experimentally. In this talk I will present local compressibility measurements of magic-angle twisted trilayer graphene in which a variety of topological correlated insulating states are observed. The local nature of the probe enables us to disentangle the contribution of the dispersive bands and identify novel phase transitions in which these degrees of freedom play a key role, underscoring the dispersive bands’ importance in the system.

Geometry and Multi-Gap States

Robert-Jan Slager

University of Cambridge

In this talk, I will discuss multi-gap states that fall beyond symmetry-based classification schemes and can results in uncharted invariants, an archetypal example being Euler class. I will address how such states depend intricately on the partition of the Hilbert space and present general geometrical approaches to characterise multi-gap topology. After shortly discussing specific progress in terms of material realisations, I will then turn to novel pursuits in the study of the out-of-equilibrium physics of multi-gap topological states, addressing both quench signatures that relate to generalised Hopf maps as well as novel anomalous Floquet realisations that are anticipated to be experimentally viable.

Induced Superconductivity in the Fractional Quantum Hall Edge in Graphene Heterostructures

Philip Kim

Harvard University

Topological superconductors represent a phase of matter whose properties cannot be smoothly changed from one phase to another, a robustness which renders them suitable for quantum computing. The past decade has witnessed substantial progress towards a qubit based on Majorana modes, non-Abelian excitations whose exchange—braiding—produces topologically protected logic operations. However, because braiding Majoranas cannot provide a universal quantum gate set, Majorana qubits are computationally limited. This drawback can be overcome by parafermions, a novel set of non-Abelian modes whose array supports universal topological quantum computation. The primary route to synthesize parafermions involves inducing superconductivity in the fractional quantum Hall (fqH) edge. In this presentation we use high- quality van der Waals devices, coupled to narrow superconducting NbN, in which superconductivity and robust fqH coexist. We find crossed Andreev reflection (CAR) across the superconductor separating two counterpropagating fqH edges which demonstrates their superconducting pairing. The CAR probability of the integer edges is insensitive to magnetic field, temperature, or filling, providing evidence for spin-orbit coupling which enables the pairing of the otherwise spin-polarized edges. FqH edges, however, may show a higher CAR probability varying with temperature, an observation contrasting with that in integer edges. Control experiments show that CAR vanishes at high temperature and excitation as expected from the finite superconducting and fqH energy gaps. These results demonstrate all the required ingredients for parafermions, laying the groundwork for their experimental research in condensed matter.

Electronic Topology and Correlations in Kagome Metals

Riccardo Comin
Massachusetts Institute of Technology

The kagome lattice is a tiling of two-dimensional space comprised of corner-sharing triangles, having the same point symmetries as the honeycomb lattice (graphene) but a richer electronic structure. Recent theoretical developments suggest that the combination of magnetism, spin-orbit coupling, and geometric frustration in kagome metals is a promising platform to realize phenomena at the intersection of topology and strong correlations, such as the fractional quantum Hall and intrinsic anomalous Hall effect. Here, a major role is played by the three distinctive features of the kagome electronic band structure, namely the Dirac points, the van Hove singularity, and the flat bands. In this talk, I will report on studies of the experimental band structure of various kagome compounds to highlight the rich physics arising from the combination of topology, magnetism, and correlations, and the prospects for realizing new quantum matter phenomena in this class of materials.

In the first part, I will discuss the family of transition metal stannides (Fe3Sn2, FeSn, and CoSn). In these systems which intertwine robust magnetism and electronic topology, we observed various manifestations of topological physics. These include the realization of the Kane-Mele model for 2D Dirac fermions with a spin-orbit-induced topological gap, as well as the discovery of the elusive flat bands with nontrivial topology.

In the second part, I will discuss our most recent studied of the AV3Sb5 family of correlated kagome metals, where superconductivity and charge-density-waves have been found to coexist. Here, I will focus on the role of the van Hove singularity in creating the conditions for multiple instabilities of the Fermi surface and the emergence of collective electronic phases.

Quotient Symmetry Protected Topological Phenomena and Quantum Criticality

Frank Pollmann

Technical University of Munich

Topological phenomena are commonly studied in phases of matter which are separated from a trivial phase by an unavoidable quantum phase transition. This can be overly restrictive, leaving out scenarios of practical relevance—similar to the distinction between liquid water and vapor. We show that topological phenomena can be stable over a large part of parameter space even when the bulk is strictly speaking in a trivial phase of matter. In particular, we focus on symmetry-protected topological phases, which can be trivialized by extending the symmetry group. We demonstrate a direct continuous quantum phase transition can stabilized by a quotient group that emerges as low-energy symmetry.

A Topological Principle for Photovoltaics

Aris Alexandradinata

University of California, Santa Cruz

To realize an efficient solar cell without inhomogeneous doping, one would like to maximize the shift component of the bulk photovoltaic current, in noncentric semiconductors with wide band gaps. I achieve this maximization for a new class of topological insulators whose band topology is only compatible with a polar crystal class. For such insulators, it is impossible to continuously tune the k-dependent electron-hole dipole moment (or `shift vector') to zero throughout the Brillouin zone. Averaging the shift vector over all high-symmetry cross-sections of the Brillouin zone gives exactly a rational multiple of a Bravais lattice vector, which points parallel to the polar axis. Even with wide band gaps, the frequency-integrated shift conductivity of intrinsically polar insulators greatly exceeds e^3/h^2, and is at least three orders of magnitude larger than the conductivity of the prototypical ferroelectric $BaTiO_3$, challenging a widely-held expectation that small band gaps are necessary for large shift currents in topological materials.

Large Magnetotransport Responses of Topological Van Der Waals Magnets

Jun Sung Kim
Department of Physics, Pohang University of Science and Technology (POSTECH), South Korea

Two dimensional topological semimetals and semiconductors, whose low energy electronic structure possesses band contact points or lines, are generally expected to exhibit novel transport responses. Particularly, when combined with magnetism, topological band degeneracy can be readily tuned by spin configuration or orientation, offering an efficient magnetic control of electronic conduction. In this talk, I will introduce van der Waals (vdW) magnets, where combination of magnetism, spin-orbit interaction, and orbital-driven topological band degeneracy gives rise to large magnetotransport responses and magnetic tunability, including large anomalous Hall effect in Fe_3GeTe_2 [1] large Nernst effect in Fe_4GeTe_2 [2] and large angular magnetoresistance in $Mn_3Si_2Te_6$ [3]. These unique transport properties clearly demonstrate that topological vdW magnets have great potential for realizing novel spin-dependent electronic functionalities, which may be suitable for spintronic applications.

[1] K.Kim, et al. Nat. Mater. 17. 794 (2018).
[2] J. Seo, et al. Sci. Adv. 6. 8912 (2020).
[3] J. Seo et al. Nature 599, 576–581 (2021).

Spin-Resolved Topology, Partial Axion Angles, and Half Quantum Spin Hall Surface States in Higher-Order Topological Crystalline Insulators

Benjamin Wieder

Université Paris-Saclay/MIT

Topological insulating (TI) phases were originally highlighted for their disorder-robust bulk responses, such as the quantized Hall conductivity of 2D Chern insulators. With the discovery of time-reversal- (T-) invariant 2D TIs, and the recognition that their spin Hall conductivity is generically non-quantized, focus has since shifted to boundary states as signatures of 2D and 3D TIs and symmetry-enforced topological crystalline insulators (TCIs). However, in T-invariant (helical) 3D TCIs such as bismuth, BiBr, and $MoTe_2$ - termed higher-order TCIs (HOTIs) - the boundary signatures manifest as 1D hinge states, whose configurations are dependent on sample details. It is hence desirable to elucidate bulk signatures of helical TCIs, and their relationship to sample-independent experimental observables. Using flux insertion, position-space partial Chern markers, and newly introduced nested spin-resolved Wilson loops and spin-resolved layer constructions, we fully characterize the bulk topological properties of inversion- and T-protected helical HOTIs. We discover that helical HOTIs realize one of three spin-resolved phases with distinct responses that are quantitatively robust to large deformations of the bulk spin-orbital texture: 3D quantum spin Hall insulators, "spin-Weyl" semimetal states with gapless spin spectra, and T-doubled axion insulator (T-DAXI) states with nontrivial partial axion angles indicative of a 3D spin-magnetoelectric bulk response. We provide experimental signatures of each spin-stable regime of helical HOTIs, including surface Fermi arcs in spin-Weyl semimetals under strong Zeeman fields, and half-quantized 2D TI states on the gapped surfaces of T-DAXIs originating from a partial parity anomaly.

Quantum Geometry and Fractional Chern Insulators in Moiré Materials

Emil Johansson Bergholtz
Stockholm University

The flatbands of Moiré materials provide a rich playground for the study of strongly correlated phases of matter. I will discuss the emergence of fractional Chern insulators in these systems, as well as novel symmetry breaking competing states emerging as a consequence of the underlying quantum geometry of the flatbands.

Zero-Field Superconducting Diode Effect in Twisted Trilayer Graphene

Mathias Sebastian Scheurer
University of Innsbruck

The semiconducting diode, which is characterized by a highly asymmetric current-voltage relation, is central to modern-day electronics. In the last few years, its superconducting analogue – a system that, for a certain magnitude of the current, behaves like a superconductor for current flow in one direction but exhibits finite resistance when the current direction is reversed – has attracted attention in the physics community, due to its potential for future quantum-electronics applications. This “superconducting diode effect” has been demonstrated in the presence of external magnetic fields, or using proximitized magnetic materials, and in magnetic as well as field-free superconducting junctions. Recently, the superconducting diode effect has also been observed at zero external magnetic field in the superconducting phase hosted by a moiré superlattice consisting of three graphene layers with the middle layer twisted against the outer two [1]. After a short introduction to twisted trilayer graphene, I will discuss possible origins [2] of the effect and the consequences for the correlated many-body physics of the system.

[1] Lin, Siriviboon, Scammell, Liu, Rhodes, Watanabe, Taniguchi, Hone, MS, and Li, Nature Physics (2022).
[2] Scammell, Li, MS, 2D Mater. 9, 025027 (2022).

Topological Material Search via Symmetry Indicator and Filling Anomaly

Haruki Watanabe
U Tokyo, Japan

Crystalline symmetries enrich the variety of insulators and superconductors.

Some of topological insulators can be detected by the symmetry-indicator method via irreducible representations of occupied bands. In this talk, I will first review recent advances of symmetry-indicator methods for superconductors.

Then I discuss a class of topological superconductors that cannot be seen by symmetry indicators. There are also a series of trivial insulators that exhibit nontrivial charges at corners and hinges. I discuss useful formulas that characterize these materials.

Electrical Switching of Magnetic Order in Intrinsic Chern Insulators

Charles Tschirhart
UC Santa Barbara

A variety of intrinsic magnetic Chern insulators have been discovered in moiré superlattice systems, including in both graphene and transition metal dichalcogenide heterostructures. Unlike in previously discovered magnetic Chern insulators, fabricated by adding magnetic dopants to thin films of topological insulators, these systems have magnetism supported entirely by electronic interactions intrinsic to the topological bands. This fact helps limit disorder in these systems by removing the need for magnetic dopants, but it also intimately ties the magnetic order to electronic properties of the system, and thus facilitates electronic control of magnetism. I will discuss electronic switching of magnetization in Chern insulators through two different mechanisms: topological contributions to magnetization and intrinsic spin-orbit torques. I will discuss these mechanisms in the context of twisted bilayer graphene, twisted monolayer/bilayer graphene, and AB-$MoTe_2/WSe_2$ using transport measurements and magnetic imaging performed with our nanoSQUID microscope.

Topological Non-Hermitian Origin of Surface Maxwell Waves

Franco Nori

RIKEN, Japan, and University of Michigan, USA

Maxwell electromagnetism, describing the wave properties of light, was formulated 150 years ago. More than 60 years ago it was shown that interfaces between optical media (including dielectrics, metals, negative-index materials) can support surface electromagnetic waves, which now play crucial roles in plasmonics, metamaterials, and nano-photonics. Here we show that surface Maxwell waves at interfaces between homogeneous isotropic media described by real permittivities and permeabilities have a topological origin explained by the bulk-boundary correspondence. Importantly, the topological classification is determined by the helicity operator, which is generically non-Hermitian even in lossless optical media. The corresponding topological invariant, which determines the number of surface modes, is a Z4 number (or a pair of Z2 numbers) describing the winding of the complex helicity spectrum across the interface. Our theory provides a new twist and insights for several areas of wave physics: Maxwell electromagnetism, topological quantum states, non-Hermitian wave physics, and metamaterials.

Persistent Homology Analysis of Phase Transitions

Daniel Leykam
National University of Singapore

There is growing interest in applying machine learning techniques to better understand complex physical systems, including topological and correlated quantum phases of matter [1]. Popular techniques such as deep learning however require a large amount of data, which may not be readily available. This limitation motivates the use of topological machine learning methods tailored to extract relevant information from sparse data. For example, the technique of persistent homology computes topological features over a range of scales, recording the scales at which features such as clusters and cycles in point cloud data appear and are destroyed. This allows one to distinguish meaningful features which persist over a large range of scales from less-robust features with low persistence. Persistent homology has been applied to various physical systems, including the detection of phase transitions in classical and quantum spin models, where point cloud data can be replaced by ensembles of spin configurations or the system's eigenfunctions. I will provide a brief overview of recent applications of persistent homology to condensed matter physics [2], including the identification of order-disorder transitions in a generalized Aubry-Andre-Harper model [3].

References

[1] J. Carrasquilla, Machine learning for quantum matter, Advances in Physics: X 5, 1797528 (2022).

[2] D. Leykam and D. G. Angelakis, Topological data analysis and machine learning, arXiv:2206.15075.

[3] Y. He, S. Xia, D. G. Angelakis, D. Song, Z. Chen, D. Leykam, Persistent homology analysis of a generalized Aubry-Andre-Harper model, arXiv:2204.13276.

Natural Superlattice Design of Quantum Materials

Joseph George Checkelsky
MIT

Connecting theoretical models for exotic quantum states to real materials is a key goal in quantum materials synthesis. Two-dimensional model systems have been proposed to host a wide variety of exotic phases- historically a number of techniques have been used to realize these including thin film growth and mechanical exfoliation. We describe here our recent progress in experimentally realizing 2D model systems using bulk crystal synthesis including superconducting and topological states. We discuss their structures and the new phenomena that they support. We comment on the perspective for realizing further 2D model systems in complex material structures and their connections to other methods for realizing 2D systems.

Nonlinear Bosonization of Fermi Surfaces: The Method of Coadjoint Orbits

Dam T. Son

University of Chicago

Fermi liquid theory is a cornerstone of condensed matter physics. However, Landau's formulation of Fermi liquid theory does not fit into the paradigm of effective field theory. We describe a new method that leads to a field-theoretical reformulation of Landau Fermi liquid theory. In this approach, a system with a Fermi surface is described as a coadjoint orbit of the group of canonical transformations. The method naturally leads to a nonlinear bosonization of the Fermi surface. The Berry phase that the Fermi surface acquires when changing shape is shown to be given by the Kirillov-Kostant-Souriau symplectic form on the coadjoint orbit. We show that the resulting local effective field theory captures both linear and nonlinear effects in Landau's Fermi liquid theory. Possible extensions and applications of the theory are described. (Reference: Luca Delacrétaz, Umang Mehta, Yi-Hsien Du, DTS arXiv:2203.05004.)

Twisted Bilayer Magnets CrI3

Moon Jip Park
IBS PCS

Recent experiments with twisted bilayer materials have provided a versatile platform for the realization of exotic phases of matter. In this talk, we are going to expand the theory of moire systems to spin systems. Starting from the brief review of twisted bilayer graphene, we develop a concrete theory of twisted bilayer magnetism. Based on the first-principles calculations of two-dimensional honeycomb magnet CrI3, we construct the generic spin models that represent a broad class of twisted bilayer magnetic systems. Using the Monte-Carlo method, we discover a variety of non-collinear magnetic order that has been overlooked in previous theoretical and experimental studies. Finally, we show that the twisted magnets can be a promising candidate for the discovery of topological magnon excitations.

Topological Phases of Discrete Unitary Dynamics

Jeongwan Haah
Microsoft

A topological phase of matter may be defined as an equivalence class of ground states of a gapped family of Hamiltonians. This equivalence relation transcribes into one by local quantum circuits of small depth. We ask an analogous question to discrete time evolution operator modulo quantum circuits of small depth on lattices. It has been known that lattice translation gives an interesting example, but recently a new class of examples have been discovered in three spatial dimensions and higher, with a connection to anomalous boundary topological order. Here, I present a complete classification result in the Clifford category in all spatial dimensions. The result exhibits periodicity in sufficiently high dimensions and is given by Witt group of prime fields.

Metrology of Band Topology via Resonant Inelastic X-ray Scattering

Gil Young Cho
POSTECH/IBS CALDES

Topology is a central notion in the classification of band insulators and characterization of entangled many-body quantum states. In some cases, it manifests as quantized observables such as quantum Hall conductance. However, being inherently a global property depending on the entirety of the system, its direct measurement has remained elusive to local experimental probes in many cases. Here, we demonstrate that various topological band indices can be directly probed by resonant inelastic x-ray scattering. Specifically, we show that the crystalline symmetry eigenvalues at the high-symmetry momentum points, which determine the band topology, leads to distinct scattering intensity for particular momentum and energy. Our approach can be explicitly demonstrated in several examples such as 1D Su-Schrie er-Heeger chain, 2D quadrupole insulator, 3D topological band insulator and chiral hinge insulator. Our result establishes an incisive bulk probe for the measurement of band topology.

Non-Reciprocal Frustration: Time Crystalline Order-by-Disorder Phenomenon and a Spin-Glass-like State

Ryo Hanai
APCTP

Having conflicting goals often leads to frustration. The conflict occurs, for example, in systems that cannot simultaneously minimize all interaction energy between the objects, a situation known as geometrical frustration. A typical feature of these systems is the presence of accidental ground state degeneracy that gives rise to a rich variety of unusual phenomena such as order-by-disorder and spin glasses. In this talk, I will show that a dynamical counterpart of these phenomena may arise from a fundamentally different, non-equilibrium source of conflict: non-reciprocal interactions. I will show that non-reciprocal systems with anti-symmetric coupling generically generate marginal orbits that can be regarded as a dynamical counterpart of accidental degeneracy, due to the emerging Liouville-type theorem. These “accidental degeneracies” of orbits are shown to often get “lifted” by stochastic noise or weak random disorder to give rise to order-by-disorder phenomena with the peculiarity that the emerging state usually has a time crystalline order. I further report numerical evidence of a non-reciprocity induced spin-glass-like state that exhibits aging and a power-law temporal relaxation associated with a short-ranged spatial correlation. This work provides an unexpected link between the physics of complex magnetic materials and non-reciprocal matter.

Fractonic Phases in Frustrated Magnets

Yong Baek Kim
Department of Physics, University of Toronto, Toronto, Ontario M5S 1A7, Canada

Fractonic phases of matter are novel quantum ground states supporting sub-dimensional emergent excitations with mobility restrictions. The ground state degeneracy of such phases is sub-extensive and depends on the geometry of the underlying lattice. Due to these unusual properties, fractonic phases are considered as models for quantum memory or as examples of quantum glassy behaviors. While there exist a number of exactly solvable models with interactions between multiple particles/spins, the realization of such models in real materials is extremely challenging. In this talk, we introduce a realistic quantum model of quadratic spin interactions on the breathing pyrochlore lattice, inspired by a classical spin model studied earlier. We show that the "charges" can only be created as a cluster, especially at the edge of a membrane excitation. Using the membrane operators acting on the ground state manifold, it is shown that the ground state degeneracy explicitly depends on the lattice geometry. We discuss the connection to the rank-2 tensor gauge theory and previous theoretical models of quantum spin liquids.

Chirality-Driven Electronic Topology in DNA-Type Chiral Materials

Binghai Yan

Department of condensed matter physics, Weizmann Institute of Science, Israel

In chemistry and biochemistry, chirality is the geometric asymmetry of a large group of molecules with a non-superposable mirror image, either left- or right-handed. In physics, chirality usually refers to the locking of spin and momentum, for example, in Weyl fermions and circularly polarized light. Although chirality represents seemingly unrelated characters in different fields, we find that the chiral geometry leads to topological electronic properties in chiral molecules or solids.I will talk about our recent theoretical and experimental studies on the chirality-driven topological properties of DNA-like chiral molecules and chiral organic polymers. The electronic topology is encoded in the orbital nature of the wave function, where an orbital-momentum locking appears. This orbital-momentum locking enables the chiral molecule to polarize the quantum orbital and induces spin polarization in the presence of spin–orbit coupling. The chiral orbital effect can also lead to switchable circular light emission in organic LEDs.

[1] Chirality-driven topological electronic structure of DNA-like materials, Y Liu, J Xiao, J Koo, B Yan, Nature materials 20 (5), 638-644 (2021).

[2] Interplay of Structure Chirality, Electron Spin and Topological Orbital in Chiral Molecular Spin Valves, Y. Adhikari, Tianhan Liu, Hailong Wang, Zhenqi Hua, Haoyang Liu, Eric Lochner, Pedro Schlottmann, Binghai Yan, Jianhua Zhao, Peng Xiong, submitted (2022).

[3] Anomalous circularly polarized light emission caused by the chirality-driven topological electronic properties, L Wan, Y Liu, MJ Fuchter, B Yan, arXiv:2205.09099 (2022).

Machine Learning Quantum Emergence

Eun-Ah Kim
Cornell University

Decades of efforts in improving computing power and experimental instrumentation were driven by our desire to better understand the complex problem of quantum emergence. The resulting “data revolution” presents new challenges. I will discuss how these challenges can be embraced and turned into opportunities through machine learning. The scientific questions in the field of electronic quantum matter require fundamentally new approaches to data science for two reasons: (1) quantum mechanics restricts our access to information, (2) inference from data should be subject to fundamental laws of physics. Hence machine learning quantum emergence requires collective wisdom of data science and condensed matter physics. I will review rapidly developing efforts by the community in using machine learning to solve problems and gain new insight. I will then present my group’s results on the machine-learning-based analysis of complex experimental data on quantum matter.

Ultrafast Charge Order Dynamics in a Kagome Metal

Nuh Gedik
MIT

The recently discovered group of topological superconducting kagome metals, AV3Sb5 (A = K, Rb, Cs), host complex strongly correlated electronic phases. One of these is the charge density wave (CDW) phase which has been extensively studied recently. However, the nature of this phase and its relation to other orders is still not well understood. In my talk, I will present recent results in which we used time- and angle-resolved photoemission spectroscopy to investigate the CDW phase of CsV3Sb5. After excitation with an ultrafast laser pulse, we obtained a momentum resolved tomographic image of the CDW gap, and observed the charge order meltdown over hundreds of femtoseconds time scale. We detect coherent oscillations at various high symmetry points across the electronic band-structure, and identify these modes as CDW induced phonons, in good agreement with recent Raman measurements. In contrast, measuring the in-gap intensity dynamics reveals two new modes that were not previously detected by any other spectroscopic method. Our experimental results distinguish these modes from the phonon modes, and using DFT calculations, we show that they correspond to the collective excitations of the order parameter.

Recent Progress in Non-Hermitian Physics beyond One Dimension

Zhong Wang
Tsinghua University

Recently, it has been found that non-Hermitian systems exhibit unique topological physics beyond the conventional framework of Bloch band theory. A revised band theory based on the concept of generalized Brillouin zone, known as the non-Bloch band theory, has been formulated to understand non-Hermitian topology and dynamics. Beyond one spatial dimension, non-Hermitian phenomena become even richer. For example, the non-Hermitian skin effect and non-Bloch parity-time symmetry have dramatic new features compared to those of one dimension. In this talk, I will introduce our recent work in non-Hermitian physics beyond one dimension.

The Topological Origin of Non-Hermitian Skin Effect

Chen Fang
Chinese Academy of Sciences

In this talk, I will show that the skin effect is understood as a particular type of the bulk-edge correspondence that is unique to non-Hermitian systems: from the spectral winding in the bulk to the skin modes on the edge. Starting in 1D, I first show that the existence of skin effect is solely determined by the spectral winding of the U(1)-phase of the complex "energy". Then I will show that in two and higher dimensions, the skin effect is absent if and only if the spectral area of the bulk vanishes. Different from 1D, in 2D and higher dimensions, the skin effect is completely compatible with all spatial symmetries, and certain spatial symmetries may protect a new type of skin effect, the geometry-dependent skin effect, that is unique to higher-than-one dimensions.

Emergence of Local Pairing and Global Phase Coherence in Underdoped Cuprates

Yayu Wang
Department of Physics, Tsinghua University

The mechanism of high temperature superconductivity in the cuprates remains an outstanding puzzle despite more than 30 years of intense research. One of the few consensuses is that the parent compound is a Mott insulator with strong onsite Coulomb repulsion, and superconductivity emerges when the doped charge carriers become mobile. A key task is thus to understand the electronic structure evolution of the doped Mott insulator.

In this talk, we report scanning tunneling microscopy studies of the atomic scale electronic structure of cuprates with increasing doping levels. We first show how the low energy electronic states emerge within the charge transfer gap when one hole and two holes are introduced into the parent compound. They can be regarded as hydrogen atom and molecule in a Mott insulator background, and exhibit characteristic spatial distributions reminiscent of molecular orbitals. When a few percent of holes are dispersed into the Mott insulator, they self-assemble into small islands of checkerboard consisting of puddles with size around 4 a_0. Even in the insulating sample, we observe the existence of superconducting-like gap with size around 10 meV when approaching the checkerboard island from the Mott insulator phase. Across the insulator to superconductor transition, the local spectra remain qualitatively similar, and the main difference is the enhancement of quasiparticle interferences characteristic of long-range phase coherence. We find that each checkerboard puddle contains approximately two holes, and exhibit stripy internal patterns that have strong influence on the superconducting properties. These results shed new lights on the emergence of local Cooper pairing and global phase coherence, two critical steps for the superconductivity in cuprates.

Dynamical Fractal and Anomalous Noise in Clean Magnetic Crystal

Roderich Moessner
MPIPKS Dresden

Fractals -- objects with non-integer dimension -- occur in manifold settings and scales in nature. Much effort has been expended to generate fractals for use in many-body physics.

Here, we report the discovery of an emergent dynamical fractal in a disorder-free, stoichiometric three-dimensional magnetic crystal in thermodynamic equilibrium: constraints on the dynamics of the magnetic monopole excitations in spin ice restrict these to move on an emergent, slowly-time-evolving fractal. This observation explains the anomalous exponent found in magnetic noise experiments in the spin ice compound $Dy_2Ti_2O_7$: it reflects (sub-)diffusion on a critical percolation cluster. It also resolves an old puzzle about its rapidly diverging relaxation time.

04

Posters

Poster Title

1. **Si Min Chan (National University of Singapore)**
Designer Topological and Non-Topological Flat Bands: Correlations and Superconductivity

2. **Hongchul Choi (IBS-CCES, Korea)**
Correlated Normal State Fermiology and Topological Superconductivity in UTe2

3. **Jae-Ho Han (IBS PCS, Korea)**
Magnetic interactions in Sr2RuO4 and superconducting gap symmetry

4. **Junmo Jeon (KAIST, South Korea)**
Control of Localization in the Non-Hermitian System

5. **Hee Seung Kim (KAIST, Korea)**
Variational Monte Carlo Study on the Kagome Lattice with Staggered Scalar Spin Chirality

6. **Kyoung-Min Kim (IBS PCS, Korea)**
Noncollinear Phases in Twisted Bilayer CrI3

7. **Yeongjun Kim (IBS PCS, Korea)**
Flat Band Induced Metal-Insulator Transitions for Weak Magnetic Flux and Spin-Orbit Disorder

8. **Youngjae Kim (KIAS, Korea)**
Spectroscopy on Nonequilibrium Systems

9. **Sanghoon Lee (IBS PCS, Korea)**
Critical-to-Insulator Transitions and Fractality Edges in Perturbed Flatbands

10. **Chiranjit Mondal (Seoul National University, Korea)**
Unremovable Linked Nodal Structures in Stacked Bilayer Graphene with Kekulé Texture

11. **Changgeun Oh (Ajou University, Korea)**
Bulk-Interface Correspondence from Quantum Distance in Flat Band Systems

12. **Yuting Qian (IBS-CCES, Korea)**
Magnetic Wallpaper Dirac Fermions and Three-Dimensional Magnetic Dirac Insulator

13. **Jung-Wan Ryu (IBS PCS, Korea)**
Classifications Based on Exceptional Points in Non-Hermitian Systems

14. **Ambrose Seo (University of Kentucky, USA)**
Studies on Heterostructures of Strongly Correlated, Spin-Orbit Coupled Electrons

15. **Sonu Verma (IBS PCS, Korea)**
Topological Phase Transition of Generalized Brillouin Zone

16. **Tiantian Zhang (Tokyo Institute of Technology)**
Parallel and Anti-Parallel Helical Surface States for Topological Semimetals

Notes

Notes

Program Book

IBS-APCTP Conference on

Advances in the Physics of Topological
& Correlated Matter

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