CMTC Fall Virtual Symposium 2020

Monday (10/19)
Host: Yang-Zhi Chou

2:30 pm - **Opening Remark**

2:40 pm - **The duality between fermionic supercohomology SPT and bosonic 2-group SPT phases in (3+1)D**

Speaker: Yu-An Chen
Abstract: Symmetry-protected topological (SPT) phases of matter are described by short-range entangled states. For each bosonic SPT phase described by the group cohomology, there is a fixed-point state that can be prepared by a finite depth quantum circuit (FDQC) built from the corresponding cohomology data. In this talk, I will describe a generalization for (3+1)D intrinsically interacting fermionic SPT phases known as the supercohomology phases. The derivation of the FDQC utilizes a series of exact lattice dualities that relate bosonic SPT phases with a certain 2-group symmetry to supercohomology phases. A quick overview is that gauging the Z2 1-form symmetry of a bosonic model gives a Z2 lattice gauge theory, and bosonizing a fermionic model also gives a Z2 lattice gauge theory. With careful design, these Z2 lattice gauge theories can match, and this constructs a duality between certain bosonic and fermionic models. The ideas of "gauging 1-form symmetry" and "bosonization (gauging fermion parity)" will be clearly explained. A primary result of this approach is that the “symmetry fractionalization” on fermion parity flux loops is immediate, which is the characteristic of supercohomology phases.
Reference: **https://arxiv.org/abs/2008.05652**

3:10 pm - **On the theoretical ability to identify topological wires based on transport measurements of three terminal and Coulomb blockaded devices**

Speaker: Jay Sau
Abstract: I will report on work done in the Maryland group on modeling transport measurement on Majorana nanowires. While the simple single channel effective model for such a wire can reproduce two terminal end conductance qualitatively by introducing a few fit parameters, it also indicates that uncertainties in the potential landscape leads to the possibility of two non-topological scenarios (so-called "bad" and "ugly") that can potentially produce qualitatively similar end conductance results as predicted for the topological case. This makes it crucial to understand if other characterization measurements would be more reliable in being able to identify topological nanowires. Motivated by such measurements, I will first discuss our comparison of three terminal measurements to the topological invariant in Majorana nanowires.

Three terminal devices allow measurement of 2 local and 2 non-local conductances as well as a thermal cross-conductance. The latter two classes of measurements allow, in principle, an estimate of the "gap" of a wire. The correlation of closing and reopening of a gap with the appearance of zero-bias peaks is expected to be strong evidence for a topological phase. We examine this claim by contrasting simulations of these measurements with a theoretical calculation of the topological invariant. I will also report on our modeling of Coulomb blockade transport where we assume that the lead-wire coupling is weak enough to allow thermalization of the Majorana wire. This approximation allows an efficient calculation of Coulomb blockade transport in a semi-realistic nanowire model that includes strong coupling effects of the wire to the bulk superconductor, end quantum dot potential landscapes, large number of levels near the critical point as well as near the end of superconductivity. In addition to the magnitude of the splitting we attempt to extract information from the intensity profile such as the bright-dark-bright features in the intensity.

Reference: Based on joint works with Sankar Das Sarma and CMTC students Haining Pan and Yi-Hua Lai respectively.

3:40 pm - Student Introductions

4:10 pm - Discussion

Tuesday (10/20)

Host: Ruixing Zhang

2:30 pm - Faithful derivation of symmetry indicators: A case study for topological superconductors with time-reversal and inversion symmetries

Speaker: Sheng-Jie Huang

Abstract: Topological crystalline superconductors have attracted rapidly rising attention due to the possibility of higher-order phases, which support Majorana modes on boundaries in d−2 or lower dimensions. However, although the classification and bulk topological invariants in such systems have been well studied, it is generally difficult to faithfully predict the boundary Majoranas from the band-structure information due to the lack of well-established bulk-boundary correspondence. In this talk, I will talk about a protocol for deriving symmetry indicators that depend on a minimal set of necessary symmetry data of the bulk bands and can diagnose boundary features. Specifically, to obtain indicators manifesting clear bulk-boundary correspondence, it's crucial to combine the topological crystal classification scheme in the real space and the twisted equivariant K theory in the momentum space. The key step is to disentangle the generally mixed strong and weak symmetry indicators through an algorithmic basis-matching procedure between the real-space and momentum-space approaches. We demonstrate our protocol using an example of two-dimensional time-reversal odd-parity

superconductors, where the inversion symmetry is known to protect a higher-order phase with corner Majoranas. Symmetry indicators derived from our protocol can be readily applied to ab initio database and could fuel material predictions for strong and weak topological crystalline superconductors with various boundary features.
Reference: **arXiv:2010.05947**

3:00 pm - **A Photon Mediated Peierls Transition**

Speaker: Colin Rylands
Abstract: The Peierls instability is a canonical example of phonon-driven strongly correlated physics, intimately related to topological quantum matter and exotic superconductivity. In this talk I will present a method for realizing an analogous photon-mediated Peierls transition using a system of one-dimensional tubes of interacting atoms trapped inside a multimode confocal cavity.

3:30 pm - **Hofstadter butterfly and Floquet topological insulators in minimally twisted bilayer graphene**

Speaker: Yang-Zhi Chou
Abstract: We theoretically study the Hofstadter butterfly of a triangular network model in minimally twisted bilayer graphene. The band structure manifests periodicity in energy, mimicking that of Floquet systems. The butterfly diagrams provide fingerprints of the model parameters and reveal the hidden band topology. In a strong magnetic field, we establish that *minimally* twisted bilayer graphene realizes low-energy Floquet topological insulators (FTIs) carrying zero Chern number, while hosting chiral edge states in bulk gaps. We identify the FTIs by analyzing the nontrivial spectral flow in the Hofstadter butterfly, and by explicitly computing the chiral edge states. Our theory paves the way for an *effective* practical realization of FTIs in equilibrium solid-state systems.
Reference: **Phys. Rev. Research 2, 033271 (2020)**

4:00 pm - **Discussion**

Wednesday (10/21)

Host: Sheng-Jie Huang

2:30 pm - **Fidelity of a sequence of SWAP operations on a spin chain**

Speaker: Robert E. Throckmorton

Abstract: We consider the "transport" of the state of a spin across a Heisenberg-coupled spin chain via the use of repeated SWAP gates, starting with one of two states—one in which the leftmost spin is down and the others up, and one in which the leftmost two spins are in a singlet state (i.e., they are entangled), and the others are again all up. More specifically, we transport the state of the leftmost spin in the first case and the next-to-leftmost spin in the second to the other end of the chain, and then back again. We accomplish our SWAP operations here by increasing the exchange coupling between the two spins that we operate on from a base value J to a larger value J_SWAP for a time t = \pi\hbar/4J_SWAP. We determine the fidelity of this sequence of operations in a number of situations—one in which only nearest-neighbor coupling exists between spins and there is no magnetic dipole-dipole coupling or noise (the most ideal case), one in which we introduce next-nearest-neighbor coupling, but none of the other effects, and one in which all of these effects are present. In the last case, the noise is assumed to be quasistatic, i.e., the exchange couplings are each drawn from a Gaussian distribution, truncated to only nonnegative values. We plot the fidelity as a function of J_SWAP to illustrate various effects, namely crosstalk due to coupling to other spins, as well as noise, that are detrimental to our ability to perform a SWAP operation. Our theory should be useful to the ongoing experimental efforts in building semiconductor-based spin quantum computer architectures.

Reference: **Robert E. Throckmorton and S. Das Sarma, Phys. Rev. B 102, 035439 (2020).**

3:00 pm - How to measure Hall conductivity in a superconductor

Speaker: Victor Yakovenko

Abstract: Superconductivity in some materials spontaneously breaks time-reversal symmetry, as detected by the magneto-optical polar Kerr effect. The latter is determined by the high-frequency ac Hall conductivity, but these superconductors are also expected to have non-zero spontaneous dc Hall conductivity. We propose a method for measuring the low-frequency Hall conductivity in such superconductors. The method is based on a Corbino disk geometry, where an oscillating axial magnetic field induces circular electric field, which, in turn, induces radial charge oscillations due to the Hall conductivity. The signal, albeit weak, can be picked up by a coaxial cable.

3:30 pm - Theory of Anomalous Floquet Higher-Order Topology: Classification, Characterization, and Bulk-Boundary Correspondence

Speaker: Ruixing Zhang

Abstract: Periodically-driven or Floquet systems can realize anomalous topological phenomena that do not exist in any equilibrium states of matter, whose classification and characterization require new theoretical ideas that are beyond the well-established paradigm of static topological phases. In this work, we provide a general framework to understand anomalous Floquet higher-order topological insulators (AFHOTIs), the classification of which has remained a

challenging open question. In two dimensions (2D), such AFHOTIs are defined by their robust, symmetry-protected corner modes pinned at special quasienergies, even though all their Floquet bands feature trivial band topology. The corner-mode physics of an AFHOTI is found to be generically indicated by the 3D Dirac/Weyl-like topological singularities living in the phase spectrum of the bulk time-evolution operator. Physically, such a phase-band singularity is essentially a ``footprint" of the topological quantum criticality that separates an AFHOTI from its high-frequency limit. Strikingly, these phase-band singularities feature unconventional dispersion relations that cannot be achieved on any static lattice in 3D, which, nevertheless, resemble the surface physics of 4D topological crystalline insulators. We establish the above higher-order bulk-boundary correspondence through a dimensional reduction technique, which also allows for a systematic classification of 2D AFHOTIs protected by point group symmetries. We demonstrate applications of our theory to two concrete models of AFHOTIs protected by C2 and D4 symmetries, respectively. Our work paves the way for a unified theory for classifying and characterizing Floquet topological matters.
Reference: **Rui-Xing Zhang and Zhi-Cheng Yang, in preparation**

4:00 pm - **Discussion**

Thursday (10/22)

Host: Robert E. Throckmorton

2:30 pm - **Topological Defect Networks - A Framework for Fractons**

Speaker: Danny Bulmash
Abstract: Fracton phases exhibit striking behavior, including deconfined excitations which cannot move freely in isolation and subextensive ground state degeneracy, which appears to render them beyond the standard topological quantum field theory (TQFT) paradigm for classifying gapped quantum matter. Here, we show that topological defect networks---networks of topological defects embedded in “stratified” 3+1D TQFTs---provide a unified framework for describing various types of gapped fracton phases. In this picture, the sub-dimensional excitations characteristic of fractonic matter are a consequence of mobility restrictions imposed by the defect network. We conjecture that all gapped phases, including fracton phases, admit a topological defect network description and support this claim by explicitly providing such a construction for many well-known fracton models.
Reference: **arXiv:2002.05166**

3:00 pm - **Dynamics of Renyi entropy in coupled Brownian SYK model**

Speaker: Shaokai Jian

Abstract: We study the time evolution of Renyi entropy between two coupled Brownian SYK models starting from a product state. The Renyi entropy grows linearly and then saturates to the coarse grained entropy. This Page curve is obtained by two different methods, the saddle point analysis and the operator dynamics. As a Brownian circuit, the Page curve is governed by operator dynamics, which we derive in the form of the master equation. Behind this complicated master equation, a more physical explanation is revealed with the help of saddle point method: the replica-diagonal and replica-wormhole saddles are responsible for the linear growth and the saturation of Renyi entropy, respectively.

3:30 pm - Fermi surface topology and quasiparticle properties in an anisotropic electron gas

Speaker: Seongjin Ahn

Abstract: We have carried out a comprehensive investigation on the renormalized Fermi surface and the quasiparticle properties in a two-dimensional electron gas in the presence of mass anisotropy. We first show that the interacting Fermi surface deviates from an ellipse, but not in an arbitrary way: The interacting Fermi surface has only two qualitatively distinct shapes, and its deviation from an ellipse is quantitatively rather small except for very low electron density, providing justification for the widely used elliptical Fermi surface approximation. We then investigate the quasiparticle properties by calculating the self-energy, the spectral function, the scattering rate, and the effective mass. We find novel anisotropic features of quasiparticle properties that are not captured by the commonly used isotropic approximation where the anisotropic effective mass is replaced by the isotropic averaged density-of-state mass.

Reference: arXiv: 2002.12532

4:00 pm - Discussion

Friday (10/23)

Host: Danny Bulmash

2:30 pm - Dynamical Symmetry Indicators For Periodically Driven Crystals

Speaker: Jiabin Yu

Abstract: Various exotic topological phases of periodically driven (Floquet) systems, such as phases with anomalous corner modes, have been shown to arise from crystalline symmetries. Yet, a general theory for topological classification of Floquet crystals is still absent. In this work, we propose to topologically classify Floquet crystals based on the symmetry data of the quasi-energy bands and the quotient winding data of the return map. The winding data consist of the symmetry-representation-dependent U(1) winding numbers along time, which yield the quotient winding data after a modulo operation. Based on the winding data, we further define

the dynamical symmetry indicator to sufficiently indicate the obstruction to static limits. We eventually derive the topological classifications and the dynamical symmetry indicators for all spinless and spinful plane groups, using the mathematical theory for affine monoids. Our theory is applicable to any crystalline symmetry group and can be used to predict new anomalous topological phases of Floquet crystals.
Reference: **Jiabin Yu, Rui-Xing Zhang, Zhi-Da Song, in preparation**

3:00 pm - How hard is it to prepare a Haar-random state?

Speaker: Christopher White
Abstract: On an error-corrected computer (or a classical computer!) Clifford gates are easy, and non-Clifford gates are hard. Mana is a magic monotone that lower bounds the number of non-Clifford gates required to prepare a state. We compute the average mana for Haar-random states, and find that for Hilbert space dimension $d \gg 1$ it falls short of an upper bound by a constant "Page correction". Furthermore, we find that almost all states have mana very close to the average; this allows one to distinguish a Haar distribution from a unitary t-design at high probability using a single output state (at the cost of an exponential number of measurements).

3:30 pm - Many-body level statistics of single-particle quantum chaos

Speaker: Yunxiang Liao
Abstract: Recent years have witnessed a surge of interest in quantum chaos - a subtle subject that is difficult to study and even to define. One of the diagnostics of quantum chaos is the level statistics. We investigate the many-body level statistics of noninteracting fermions populating levels of a Gaussian unitary ensemble using the random matrix theory. We find that the spectral form factor is not pure Poisson as one would normally expect for an integrable model, but possesses surprisingly rich features including an initial slope, an exponential ramp and a plateau. The exponential ramp reflects the level repulsion between distant many-body levels stemming from the underlying single-particle quantum chaos. We also use the sigma-model approach, which is generalizable to the interacting case, to study the same problem, and find that the exponential ramp originates from the soft mode fluctuations around the saddle points.
Reference: **Y. Liao, A. Vikram and V. Galitski, arXiv. 2005.08991**

4:00 pm - Discussion