Workshop: Strongly Correlated Topological Phases of Matter

Events for:
Monday, June 5th - Friday, June 9th

Monday, June 5th

9:30am **Xiao-Gang Wen - SCGP 102**

Title: A classification of 3+1D topological orders

10:30am **Break - SCGP Lobby**

11:00am **Meng Cheng - SCGP 102**

12:00pm **Lunch - SCGP Cafe**

2:15pm **Zhenghan Wang - SCGP 102**

Title: Reconstructing chiral CFTs/VOAs from 2D TQFTs/MTCs

Abstract: Inspired by the bulk-edge relation of 2D topological phases of matter and Tannaka-Krein duality, we consider the reconstruction of chiral CFTs, mathematically vertex operator algebras (VOAs), from their representation categories---modular tensor categories (MTCs).

3:30pm **Tea**

4:00pm **Mathai Varghese - SCGP 102**

Title: Differential topology of semimetals

Abstract: I will discuss local and global invariants for topological semimetals using Dirac type hamiltonians in 3D and higher. Dually, a topological semimetal can be represented by Euler chains from which its surface Fermi arc connectivity can be deduced. These dual pictures, as well as the link to topological invariants of insulators, are organised using Mayer-Vietoris exact sequences. I will also discuss quadraticDirac-type Hamiltonians and introduce new classes of semimetals, leading to the prediction of torsion Fermi arcs. This is joint work with G.C. Thiang

Tuesday, June 6th

9:30am **Nathan Seiberg - SCGP 102**

10:30am **Break - SCGP Lobby**

11:00am **Zohar Komargodski - SCGP 102**

Title: Domain Walls, Anomalies, and Deconfinement in Yang-Mills Theory and in the Neel-VBS Transition.

12:00pm **Lunch - SCGP Cafe**

2:15pm **Kevin Walker - SCGP 102**

Title: Low-dimensional G-bordism and G-modular TQFTs

Abstract: Let G denote a class of manifolds (such as SO (oriented), O (unoriented), Spin, Pin+, Pin-, manifolds with spin defects, etc.). We define a 2+1-dimensional G-modular TQFT to be one which lives on the boundary of a bordism-invariant 3+1-dimensional G-TQFT. Correspondingly, we define a G-modular tensor category to be a G-premodular category which leads to a bordism-invariant 3+1-dimensional TQFT. When G = SO, this reproduces the familiar Witten-Reshetikhin-Turaev TQFTs and corresponding modular tensor categories. For other examples of G, non-zero G-bordism groups in dimensions 4 or lower lead to interesting complications (anomalies, mapping class group extensions, obstructions to defining the G-modular theory on all G-manifolds).

3:30pm **Tea**

4:00pm **Dave Aasen - SCGP 102**

Title: Fermion Condensation and Superconducting String-nets

Abstract: We study non-chiral fermionic topological phases through the lens of fermion condensation. We give a prescription for performing fermion condensation in generic bosonic topological phases which contain an emergent fermion. Our approach to fermion condensation can roughly be understood as coupling the parent bosonic topological phase to a phase of physical fermions and condensing pairs of physical and emergent fermions. In contrast to the bosonic fusion categories, the simple objects in the fermionic fusion categories can have endomorphism algebras isomorphic to the complex Clifford algebras. We define a fermionic version of the tube category, providing a framework to investigate the anyonic content of the associated fermionic string-net Hamiltonians. We will highlight generic properties of the fermionic string-nets with several examples.

Wednesday, June 7th

9:30am **Fiona Burnell - SCGP 102**

10:30am **Break - SCGP Lobby**

11:00am **Dominic Else - SCGP 102**

Title: Gauging spatial symmetries and the classification of topological crystalline phases

Abstract: The classification of topological phases of matter becomes richer when we incorporate symmetries. A "crystalline topological phase" is a topological phase that is invariant under a group of spatial symmetries. I will discuss a very general approach to classifying such phases based on a notion of "gauging" a spatial symmetry. From this framework one can derive a "Crystalline Equivalence Principle", which states that for systems occupying Euclidean space R^d, the classification of phases with spatial symmetry G is in one-to-one correspondence with the classification of phases with G acting *internally*. For systems occupying a general space X, one finds that bosonic phases without intrinsic topological order (SPT phases) are classified by the equivariant cohomology H^{d+1}_G(X, U(1)), which reduces to group cohomology H^{d+1}(G, U(1)) when X = R^d. I will discuss a spectral sequence that computes this equivariant cohomology and its physical content, leading to simple physical interpretations of the corresponding phases of matter.

12:00pm **Lunch - SCGP Cafe**

2:15pm **Zheng-Cheng Gu - SCGP 102**

Title: A topological world: From topological phases of quantum matter to the origin of elementary particles.

Abstract: In this talk, I will give an introduction for topological phases of quantum matter. In particular, I will describe the mathematical foundation of 3+1D symmetry protected topological(SPT) phases and their corresponding classification schemes in interacting fermion systems. If time permits, I will also mention a potential new understanding for the origin of elementary particles.

3:30pm **Tea**

4:00pm **Lesik Motrunich - SCGP 102**

Title: Two stories of exact self-duality and criticality in 2+1 dimensions

Abstract: It is very rare in 2+1-dimensional statmech/many-body systems to know exact locations of phase transitions. I will present studies of two cases where this is possible due to exact self-duality in some variables. In the first part, I will consider a model of one species of bosons with marginally-long-range interactions in 2+1d and with time reversal symmetry. At a special strength of the interaction the model is exactly self-dual and hence is at a phase transition separating boson "superfluid" and "insulator" phases, and our numerical studies show that this phase transition is continuous. Remarkably, a model of one species of Dirac fermions with marginally long-range-interactions and time reversal also has such an exactly self-dual special point, and even more remarkably, at this point it is equivalent to the exactly-self-dual time-reversal-invariant bosons. In the second part, I will consider a model of two species of bosons with short-range interactions realizing a transition from a bosonic SPT phase (a.k.a. integer quantum Hall state of bosons) to a trivial insulator phase. We show that species interchange symmetry and a non-local antiunitary particle-hole-like symmetry place the model exactly at the phase boundary between the SPT and trivial phases. Remarkably, such model placed at the transition is equivalent to so-called easy-plane NCCP1 model at its exact self-duality. Our numerical studies show that in the simplest such model the transition is first-order. However, we hope that our mappings and recent renewed interest in such self-dual models will stimulate more searches for models with a continuous transition; to this end, we propose generalizations of our models that can be similarly places exactly at the transition and pursued in future Monte Carlo studies.

Thursday, June 8th

9:30am **Dima Feldman - SCGP 102**

Title: Particle-hole symmetry without particle-hole symmetry in the quantum Hall effect at Î½ = 5/2

Abstract: Numerical results suggest that the quantum Hall effect at the filling factor 5/2 is described by the Pfaffian or anti-Pfaffian state in the absence of disorder and Landau level mixing. Those states are incompatible with the observed transport properties of GaAs heterostructures, where disorder and Landau level mixing are strong. We show that the recent proposal of a PH-Pfaffian topological order by D. T. Son is consistent with all experiments. The absence of the particle-hole symmetry at the filling factor 5/2 is not an obstacle to the existence of the PH-Pfaffian order since the order is robust to symmetry breaking.

10:30am **Break - SCGP Lobby**

11:00am **Yuan-Ming Lu - SCGP 102**

Title: Lieb-Schultz-Mattis theorems for symmetry-protected topological phases

Abstract: The Lieb-Schultz-Mattis (LSM) theorem and its descendants represent a class of powerful no-go theorems that rule out any short-range-entangled (SRE) symmetric ground state irrespective of the specific Hamiltonian, based only on certain microscopic inputs such as symmetries and particle filling numbers. In this work, we introduce and prove a new class of LSM-type theorems, where any symmetry-allowed SRE ground state must be a symmetry-protected topological (SPT) phase with robust gapless edge states. The key ingredient is to replace the lattice translation symmetry in usual LSM theorems by magnetic translation symmetry. These theorems provide new insights into numerical models and experimental realizations of SPT phases in interacting bosons and fermions.

12:00pm **Lunch - SCGP Cafe**

2:15pm **Maissam Barkeshli - SCGP 102**

Title: Reflection and time reversal symmetry enriched topological phases of matter

Abstract: I will discuss recent work developing an understanding of reflection and time reversal symmetry in (2+1)D topological phases of matter. This includes an understanding of path integrals of topological quantum field theories on non-orientable manifolds, and anomalies associated with time-reversal / reflection symmetry.

3:30pm **Tea**

4:00pm **Lakshya Bhardwaj - SCGP 102**

Title: Turaev-Viro Construction of (2+1)D Unoriented TQFTs

Abstract: I will propose a construction of unoriented (2+1)D TQFTs in terms of what I call "twisted" spherical fusion categories. From the condensed matter point of view, this can be viewed as a construction of bosonic gapped phases of matter with time-reversal symmetry. This construction extends a well-known construction (due to Turaev and Viro) of oriented (2+1)D TQFTs in terms of spherical fusion categories.

Friday, June 9th

9:30am **Valentin Zakherevich - SCGP 102**

Title: Verlinde ring for non-connected Lie groups and gauging finite group symmetries

Abstract: Given a short exact sequence of finite groups $1\rightarrow H\rightarrow G\rightarrow K\rightarrow1$ and a K-invariant class $\alpha_{H}\in H^{n}(BH,U(1))$, there is an action of K on the n-dimensional Dijkgraaf-Witten theory associated with the pair (H,α_{H}). Extending the symmetry action in a higher-categorical sense is equivalent to extending the class α_{H} to a class $\alpha_{G}\in H^{n}(BG,U(1))$. Gauging this action one obtains the Dijkgraaf-Witten theory corresponding to the pair (G,α_{G}). We ask: ``Does the analogous statement holds if the group H is allowed to be a compact Lie group and the Dijkgraaf-Witten theory is replaced by the Chern-Simons theory?" The difficulty lies in understanding the Chern-Simons theory for the non-connected Lie group G. By a theorem of Freed, Hopkins, and Teleman, the corresponding Verlinde ring is isomorphic to the twisted equivariant K-theory $K_{G}^{\tau}(G)$ where G acts on itself by conjugation and the fusion is given by the Pontryagin product, i.e. induced from the multiplication map of G. Comparing it to the Verlinde ring of the gauged Chern-Simons theory of H by K, as developed by Barkeshli, Bonderson, Cheng, and Wang, suggests that the answer to the question above is affirmative.

10:30am **Break - SCGP Lobby**

11:00am **Guo Chuan Thiang - SCGP 102**

Title: Time-reversal in topological semimetals

Abstract: Experimentally realised Weyl semimetals have time-reversal invariance, but their topological indices had not been properly understood in this setting. It turns out that Weyl points become a new type of "Fu-Kane-Mele monopole", and that their creation-annihilation histories provide a simple and mathematically equivalent way to classify semimetals. The surface Fermi arcs and Dirac cones coexist in a subtle way and may transmute between each other without a topological phase transition. Interface surface state topology can be easily inferred, and is verified by numerical calculations.

12:00pm **Lunch - SCGP Cafe**

1:30pm **Emil Prodan - SCGP 102**

Title: Elements of Kasparovâ€™s K-Theory for Correlated and Disordered Systems

Abstract: K-Theory for operator algebras played an essential role in our understanding of the stability of topological invariants of un-correlated systems in the presences of strong disorder. Kasparovâ€™s generalization, widely known as KK-Theory, seems to provide the right framework for treating the correlated and disordered topological phases. In the first part of my talk, I will review the core of Kasparovâ€™s K-theory and indicate connections to Alain Connesâ€™ program in Non-Commutative Geometry, together with index theorems that have been obtained for disordered topological insulators. In the second part, I will discuss one correlated case which is treated within this formalism.

3:30pm **Tea**