

Workshop

Events for:
Monday, May 24th - Friday, May 28th

Monday, May 24th

10:00am **Thomas Quella**

Title: Symmetry-protected topological phases beyond groups

10:15am **Meng Cheng**

Title: Fractonic and compressible phases in layered Chern-Simons theory

10:30am **Break and Q&A**

11:00am **Clement Delcamp**

Title: Closing string-like excitations in (3+1)d topological phases

Abstract:

11:15am **Sagar Vijay**

Title: Hybrid Fracton Orders Part 1

Abstract: We introduce hybrid fracton orders: three-dimensional gapped quantum phases that exhibit the phenomenology of both conventional three-dimensional topological orders and fracton orders. Hybrid fracton orders host both (i) mobile topological quasiparticles and loop excitations, as well as (ii) point-like topological excitations with restricted mobility, with non-trivial fusion rules and mutual braiding statistics between the two sets of excitations. In Part I, we present examples of orders which "hybridize" known fracton orders such as the X-Cube model and Haah's code with that of a 3D Z_n topological order. In Part II, we present orders which can host non-Abelian fracton excitations, along with a family of exactly solvable models for any finite group G and normal subgroup N -- termed (G,N) gauge theories -- which yield hybrid orders. Universal properties of these phases may be related to the group structure of G and N . In select situations, these models can be understood to interpolate between the quantum double and a pure fracton order.

11:30am **Nat Tantivasadakarn**

Title: Hybrid Fracton Orders Part 2

Abstract: We introduce hybrid fracton orders: three-dimensional gapped quantum phases that exhibit the phenomenology of both conventional three-dimensional topological orders and fracton orders. Hybrid fracton orders host both (i) mobile topological quasiparticles and loop excitations, as well as (ii) point-like topological excitations with restricted mobility, with non-trivial fusion rules and mutual braiding statistics between the two sets of excitations. In Part I, we present examples of orders which "hybridize" known fracton orders such as the X-Cube model and Haah's code with that of a $3D Z_n$ topological order. In Part II, we present orders which can host non-Abelian fracton excitations, along with a family of exactly solvable models for any finite group G and normal subgroup N -- termed (G,N) gauge theories -- which yield hybrid orders. Universal properties of these phases may be related to the group structure of G and N . In select situations, these models can be understood to interpolate between the quantum double and a pure fracton order.

11:45am **Break and Q&A**

12:15pm **Yichen Hu**

Title: From A to D: Gauging Dihedral Symmetry in the Orthogonal Family

Abstract:

12:30pm **Leo Radzihovsky**

Title: Smectic Gauge Theory

Abstract:

12:45pm **Break and Q&A**

Tuesday, May 25th

10:00am **Alex Turzillo**

Title: SPTO under Quantum Channels

Abstract: I will discuss symmetry conditions on quantum channels and their relation to SPT phases of mixed states.

10:15am **Taylor Hughes**

Title: Many-Body Electric Multipole Insulators

Abstract: In this talk we discuss many-body electric multipole insulators with dipole conserving symmetries. We present rank-2 response theories for a 2D quadrupole insulator and a 3D chiral hinge insulator. We show how many-body operators for determining electric multipoles can be used to make a criterion for distinguishing multipole metals and multipole insulators in systems with conserved multipole moments.

10:30am **Break and Q&A**

11:00am **Xiao-Gang Wen**

Title: A systematic construction of gapped non-liquid states

Abstract: Gapped non-liquid state (also known as fracton state) is a very special gapped quantum state of matter that is characterized by a microscopic cellular structure. Such microscopic cellular structure has a macroscopic effect at arbitrary long distances and cannot be removed by renormalization group flow, which makes gapped non-liquid state beyond the description of topological quantum field theory with a finite number of fields. Non-liquid topological states can be constructed via a "tensor network" of 2d domain walls between 3d topological orders (or 3d product states). The constructed cellular topological states can be viewed as a fixed-point of a reverse renormalization of gapped non-liquid states.

11:15am **Ruben Verresen**

Title: Towards realizing toric code topological order in the lab

Abstract: Experimentally realizing the exotic phases discussed in this workshop is a great challenge. This talk presents a 'how-to' guide for the simplest type of topological order. I will explain how the strong interactions between Rydberg atom systems can be used to engineer quantum dimer models. Driving the atoms with lasers induces quantum resonances which can stabilize a Z_2 quantum dimer liquid. The relevant physics is already captured in a simple PXP-type model. The onset of topological order can be probed in numerics and experiment by measuring its two topological string observables, giving access to the Fredenhagen-Marcu order parameters which provide a unique fingerprint.

11:30am **Frank Pollmann**

Title: Fractal Quantum Phase Transitions

11:45am **Break and Q&A**

12:15pm **Dom Williamson**

Title: A recipe for topological defect networks

Abstract: I will introduce a general recipe to construct a stable topological defect network for any (CSS) topological stabilizer Hamiltonian. I will go on to demonstrate this recipe in action for the example of Haah's cubic code.

12:30pm **Wilbur E. Shirley**

Title: Hidden duality in a 4+1d topological order

12:45pm **Break and Q&A**

1:15pm **Roderich Moessner**

Title: Topological route to new -- and higher rank -- spin liquids

1:30pm **Daniel Bulmash**

Title: Anomalies in (2+1)D fermionic topological phases

Abstract: Symmetry-enriched topological (SET) phases in (2+1)D may in general be anomalous, in that the symmetry acts consistently on the anyons but the phase cannot be realized in (2+1)D with the symmetry generated onsite and must instead live on the surface of a (3+1)D symmetry-protected topological (SPT) state. We show how to compute the anomaly in (2+1)D fermionic SETs, that is, given a (2+1)D fermionic topological order and a symmetry fractionalization class for a global symmetry group G , we show how to construct a (3+1)D topologically invariant path integral for a fermionic G -SPT in terms of an exact combinatorial state sum. As an example, we show that our construction reproduces the Z_{16} anomaly indicator for time-reversal symmetric topological superconductors with $T^2 = (-1)^F$. Mathematically, with some standard technical assumptions, this implies that our construction gives a combinatorial state sum on a triangulated 4-manifold that can distinguish all Z_{16} Pin+ smooth bordism classes and can thus distinguish exotic smooth structure.

1:45pm **Break and Q&A**

Wednesday, May 26th

10:00am **Masaki Oshikawa**

Title: Resolving the Berezinskii-Kosterlitz-Thouless transition in the 2D XY model with TNR+CFT

Abstract: The Berezinskii-Kosterlitz-Thouless (BKT) transition was historically the first example of topological phase transitions. Here we re-investigate the BKT transition in the 2D classical XY model, combining the Tensor Network Renormalization (TNR) and the Level Spectroscopy method based on the finite-size scaling of the Conformal Field Theory. By systematically analyzing the spectrum of the transfer matrix of the systems of various moderate sizes which can be accurately handled with a finite bond dimension, we determine the critical point removing the logarithmic corrections. This improves the accuracy by an order of magnitude over previous studies including those utilizing TNR. Our analysis also gives a visualization of the celebrated Kosterlitz Renormalization Group flow based on the numerical data. Reference: Atsushi Ueda and M.O., to appear in arXiv on May 26th

10:15am **Sanjay Moudgalya**

Title: Hilbert Space Fragmentation and Commutant Algebras

Abstract: In this talk, I will discuss the phenomenon of Hilbert space fragmentation using the language of commutant algebras, the algebra of all operators that commute with each term of the Hamiltonian. This formalism provides a concrete definition for Hilbert space fragmentation, distinguishes fragmentation from conventional symmetries such as $U(1)$ or $SU(2)$, and also helps distinguish between various types of fragmentation.

10:30am **Break and Q&A**

11:00am **John Sous**

Title: Fracton-like quasiparticles in hole-doped antiferromagnets

11:15am **Abhinav Prem**

Title: Spectral statistics in many-body quantum chaotic systems with constraints

Abstract: We study the spectral statistics of spatially-extended many-body quantum systems with on-site Abelian symmetries or local constraints, focusing primarily on those with conserved dipole and higher moments. In the limit of large local Hilbert space dimension, we find that the spectral form factor of Floquet random circuits can be mapped exactly to a classical Markov circuit, and, at late times, is related to the partition function of a frustration-free Rokhsar-Kivelson (RK) type Hamiltonian. Through this mapping, we show that the inverse of the spectral gap of the RK-Hamiltonian lower bounds the Thouless time of the underlying circuit. For systems with conserved higher moments, we derive a field theory for the corresponding RK-Hamiltonian by proposing a generalized height field representation for the Hilbert space of the effective spin chain. Using the field theory formulation, we obtain the dispersion of the low-lying excitations of the RK-Hamiltonian in the continuum limit, which allows us to extract the Thouless time. In particular, we analytically argue that in a system of length L that conserves the m -th multipole moment, the Thouless time scales subdiffusively as L^{2m+2} .

11:30am **Juven C. Wang**

Title: Ultra Unification: QFT Beyond the Standard Model

Abstract: Strong, electromagnetic, and weak forces were unified in the Standard Model (SM) with spontaneous gauge symmetry breaking. These forces were further conjectured to be unified in a simple Lie group gauge interaction in the Grand Unification (GUT). Here I propose a theory beyond the SM and GUT by adding new gapped Topological Phase Sectors consistent with the nonperturbative global anomaly cancellation and cobordism constraints (especially from the baryon minus lepton number $B - L$, the electroweak hypercharge Y , and the mixed gauge-gravitational anomaly). Gapped Topological Phase Sectors are constructed via symmetry extension, whose low energy contains unitary Lorentz invariant topological quantum field theories (TQFTs): either 3+1d non-invertible TQFT (long-range entangled gapped phase), or 4+1d invertible or non-invertible TQFT (short-range or long-range entangled gapped phase), or right-handed neutrinos, or their combinations. We propose that a new high-energy physics frontier beyond the conventional 0d particle physics relies on the new Topological Force and Topological Matter including gapped extended objects (gapped 1d line and 2d surface operators or defects, etc., whose open ends carry deconfined fractionalized particle or anyonic string excitations). I will also fill in the dictionary between math, quantum field theory (QFT), and condensed matter terminology, and elaborate on the nonperturbative global anomalies of Z_2 , Z_4 , Z_{16} classes useful for beyond SM. Work is based on arXiv:2012.15860, arXiv:2008.06499, arXiv:2006.16996, arXiv:1910.14668.

11:45am **Break and Q&A**

12:15pm **Kevin Slagle**

Title: Foliated QFT of Fracton Order

Abstract: I discuss a new kind of quantum field theory (QFT), a foliated QFT, which describes a large class of foliated fracton models. Instead of coupling to a Riemann metric, a foliated QFT couples to one or more spacetime foliations via a constraint on the gauge fields. The planon, lineon, and fracton mobility constraints are determined by this foliation structure. I will also briefly mention a new work with Po-Shen Hsin, where we study many new examples (including hybrid and nonabelian fracton models) and dualities. The talk is based on arXiv:2008.03852 and arXiv:2105.09363

12:30pm **Xiao-Chuan Wu**

Title: Gapless states with Categorical Symmetry and Large Conserved Quantities

12:45pm **Break and Q&A**

Thursday, May 27th

10:00am **Jeongwan Haah**

Title: A degeneracy bound for homogeneous topological order

10:15am **Dung Nguyen Xuan**

Title: From Lowest Landau Limit to higher rank symmetry

Abstract: I will demonstrate the relation between the lowest Landau level (LLL) limit of fractional quantum Hall (FQH) systems with a higher rank symmetry. I will show that FQH, in the LLL, enjoys the gauge symmetry that combined an area-preserving diffeomorphism and a $U(1)$ gauge transformation. The fractonic behaviour of excitations in the LLL is the consequence of the higher rank symmetry. I will also derive the GMP algebra using the non-linear version of the higher rank symmetry.

10:30am **Break and Q&A**

11:00am **Sayed Ali Akbar Ghorashi**

Title: Higher-Order Weyl Semimetals

11:15am **Rahul Mahajan Nandkishore**

Title: Spectroscopic diagnostics of spin liquids, both conventional and fractonic

11:30am **Djordje Radicevic**

Title: Local avatars of global anomalies

Abstract: Finite theories with (approximately) continuous symmetries often display simple global anomalies. For example, the global $U(1)$ symmetry of lattice fermions cannot be gauged for many choices of fermion charges. This is ultimately because the symmetry group is much larger than the target space of the theory. This phenomenon has a local manifestation that I will describe in this talk: whenever gauging is possible, the gauge fields must still obey stringent local constraints. This little fact has important implications for studying continuum limits of many lattice theories.

11:45am **Break and Q&A**

12:15pm **Michael Hermele**

Title: Subsystem symmetry fractionalization on point-like excitations

Abstract: We show via an explicit example that non-trivial subsystem symmetry fractionalization can occur on the point-like excitations of a topologically ordered phase in two spatial dimensions. A key property of our example, which allows it to avoid a recent no-go argument, is the presence of excitations whose mobility is restricted under symmetry-preserving dynamics. In this talk we describe the example model and compare and contrast its properties with fractionalization of ordinary (zero-form) global symmetries.

12:30pm **Maissam Barkeshli**

Title: Classification of fractional quantum Hall states with spatial symmetries

Abstract: We develop a systematic classification of $(2+1)D$ topologically ordered states of matter with magnetic translation symmetry and rotational symmetry, both in the continuum and on the lattice, using the framework of G -crossed braided tensor categories. This gives a systematic formulation of known results in the continuum case, and a number of new topological invariants, including new fractionally quantized responses, in the crystalline case.

12:45pm **Break and Q&A**

Friday, May 28th

10:00am **Yang Qi**

Title: Towards a classification of fermionic crystalline SPT states

Abstract: In this talk, I will briefly review our recent efforts towards a classification of fermionic crystalline-symmetry-protected topological states, which are based on two approaches. First, using the crystalline equivalence principle proposed by Thorngren and Else, the classification can be computed by treating the crystalline symmetries as onsite symmetries. We develop an algorithm that allows a fast computation of such classification for complex symmetry groups, including the space groups. Second, we use a real-space construction to build crystalline SPT states from lower-dimensional building blocks, which are topological states protected by onsite symmetries. I will discuss the progress and difficulties we are facing in each approach.

10:15am **Ethan Lake**

Title: Foliated criticality in the X-cube model

Abstract: In this talk I will discuss a few simple examples of continuous phase transitions obtained by condensing various types of excitations in the X-Cube model. Many of the critical points are stable, and can be studied using techniques from 1+1D and 2+1D conformal field theory. The condensed phases on the other side of the transition can be described as various types of deconfined gauge theories, which we demonstrate using an explicit lattice construction. This talk will be based on ongoing work with Michael Hermele.

10:30am **Break and Q&A**

11:00am **Nathan Seiberg**

Title: Lattice vs. Continuum Exotic Field Theories **Part I**

Abstract: Exotic systems (e.g., the XY-plaquette model and some models of fractons) are characterized by having subsystem global symmetries. They exhibit UV/IR mixing, i.e., some long-distance properties are sensitive to short-distance details. As such, these models challenge a standard continuum field theory description. Our previous analysis of their continuum limits exhibited emergent subsystem global symmetries (with 't Hooft anomalies) and new dualities. These continuum theories are non-standard and subtle because one needs to account for discontinuous field configurations. In order to understand better these systems, we deform the original lattice models to new ones. The new lattice models are closer to the continuum theories and they exhibit many of the emergent global symmetries (and their anomalies) and the new dualities already at the level of the lattice. Also, these new lattice models provide a clear and rigorous formulation of the continuum theories and their singularities, thus confirming our earlier analysis.

11:15am **Ho Tat Lam**

Title: Lattice vs. Continuum Exotic Field Theories **Part II**

Abstract: Exotic systems (e.g., the XY-plaquette model and some models of fractons) are characterized by having subsystem global symmetries. They exhibit UV/IR mixing, i.e., some long-distance properties are sensitive to short-distance details. As such, these models challenge a standard continuum field theory description. Our previous analysis of their continuum limits exhibited emergent subsystem global symmetries (with 't Hooft anomalies) and new dualities. These continuum theories are non-standard and subtle because one needs to account for discontinuous field configurations. In order to understand better these systems, we deform the original lattice models to new ones. The new lattice models are closer to the continuum theories and they exhibit many of the emergent global symmetries (and their anomalies) and the new dualities already at the level of the lattice. Also, these new lattice models provide a clear and rigorous formulation of the continuum theories and their singularities, thus confirming our earlier analysis.

11:30am **Shu-Heng Shao**

Title: Lattice vs. Continuum Exotic Field Theories **Part III**

Abstract: Exotic systems (e.g., the XY-plaquette model and some models of fractons) are characterized by having subsystem global symmetries. They exhibit UV/IR mixing, i.e., some long-distance properties are sensitive to short-distance details. As such, these models challenge a standard continuum field theory description. Our previous analysis of their continuum limits exhibited emergent subsystem global symmetries (with 't Hooft anomalies) and new dualities. These continuum theories are non-standard and subtle because one needs to account for discontinuous field configurations. In order to understand better these systems, we deform the original lattice models to new ones. The new lattice models are closer to the continuum theories and they exhibit many of the emergent global symmetries (and their anomalies) and the new dualities already at the level of the lattice. Also, these new lattice models provide a clear and rigorous formulation of the continuum theories and their singularities, thus confirming our earlier analysis.

11:45am **Break and Q&A**

12:15pm **Sheng-Jie Huang**

Title: Quantum many-body topology of quasicrystals

Abstract: In this talk, I will describe a general approach for understanding quasicrystalline interacting topological phases of matter i.e., phases protected by some quasicrystalline structure. We show that the elasticity theory of quasicrystals, which accounts for both “phonon” and “phason” modes, admits non-trivial quantized topological terms with far richer structure than their crystalline counterparts. We show that these terms correspond to distinct phases of matter and also uncover intrinsically quasicrystalline phases, which have no crystalline analogues. For quasicrystals with internal $U(1)$ symmetry, we will discuss a number of interpretations and physical implications of the topological terms. We will then address the general classification of quasicrystalline topological phases.

12:30pm **Fiona Burnell**

Title: TBD

12:45pm **Break and Q&A**