Quantum Matter Workshop

December 2-4, 2019

Monday, December 2

"General quantum matter and the vision"

Moderator: Nathanan Tantivasadakarn (Harvard)

Time	Speaker	Title/Abstract
8:30 - 8:50am	*Breakfast*	
8:50 - 9:00am	Welcome	Remarks by S.T. Yau
9:00 - 10:00am	Emil Prodan	**Title:** Topological Bulk-Boundary Correspondence via K-Theory **Abstract:** I will demonstrate how K-Theory becomes one of the finest tools available when it comes to establishing the bulk-boundary correspondence in aperiodic systems. For example, the closely related quasi-periodic and quasi-crystalline systems display the same bulk K-theory but they have a completely opposite edge physics: topological edge spectrum exists for the first class of systems but it is entirely absent for the second class. The K-Theory of the edge and its relation with the bulk explain the differences. I will then demonstrate how the K-Theoretic guidance lead to concrete engineering of many aperiodic meta-materials where topological pumping is possible.
10:00 - 10:30am	Daniel Jafferis	**Title:** Wormhole teleportation in the SYK model
10:30 - 11:00am	*Break*	
11:00 - 12:00pm	Liang Fu	**Title:** Supermetal

12:00 - 2:30pm *Lunch*

"Quantum gauge dynamics/criticality"

Moderator: Ruben Verresen (Harvard)

2:30 - 3:30pm	Senthil Todadri	**Title:** Some novel quantum critical phenomena **Abstract:** Despite years of study our understanding of what kinds of quantum critical points can occur and their description is very poor. In this talk I will describe several surprising such quantum critical phenomena found in recent work. Examples include multiple universality classes for the same phase transition, “unnecessary” quantum critical points, and deconfined quantum critical points in 4 space time dimensions.
3:30 - 4:00pm	*Break*	
4:00 - 4:30pm	Yunqin Zheng	**Title:** Symmetry Enriched SU(2) Yang-Mills, Time Reversal Domain Walls and Gauge Enhanced Quantum Critical Points

		Abstract:I will discuss the time reversal and Lorentz symmetry enriched SU(2) Yang-Mills theory at $\theta=\pi$. I will first review the 't Hooft anomaly of this theory and discuss how it depends on the symmetry enrichments . 't Hooft anomaly implies that the low energy theory must be nontrivial, and this talk mainly focuses two low energy scenarios. In the first scenario, the time reversal symmetry is spontaneously broken, and I'll discuss the theory on the time reversal domain wall and study its symmetry enrichments. In the second scenario, SU(2) Yang-Mills at $\theta=\pi$ flows to a deconfined time reversal symmetric U(1) Maxwell theory. I will discuss the quantum phase transition between the U(1) gauge theory to a trivial vacuum, through a SU(2) QCD with fundamental fermions. This talk is based on the work arXiv: 1910.14664, arXiv: 1904.00994 and arXiv: 1812.11968.
4:30 - 5:00pm	Zhen Bi	**Title**: Landau ordering phase transitions beyond the Landau paradigm. **Abstract:** Continuous phase transitions associated with the onset of a spontaneously broken symmetry are thought to be successfully described by the Landau-Ginzburg-Wilson-Fisher theory of fluctuating order parameters. In this work we show that such transitions can admit new universality classes which cannot be understood in terms of a theory of order parameter fluctuations. We explicitly demonstrate continuous time reversal symmetry breaking quantum phase transitions of 3 + 1-D bosonic systems described by critical theories expressed in terms of a deconfined gauge theory with massless Dirac fermions instead of the fluctuating Ising order parameter. We dub such phase transitions "Landau transitions beyond Landau description" (LBL). A key feature of our examples is that the stability of the LBL fixed points requires a crucial global symmetry, which is non-anomalous, unbroken, and renders no symmetry protected topological phase throughout the phase diagram. Despite this, there are elementary critical fluctuations of the phase transition that transform projectively under this symmetry group. We also construct examples of other novel quantum critical phenomena, notably a continuous Landau-forbidden deconfined critical point between two Landau-allowed phases in 3 + 1-D.
5:00 - 5:30pm	Eslam Khalaf	**Title:** Ground state & topological properties of magic-angle twisted bilayer graphene

Tuesday, December 3

"Exotic quantum matter (e.g. SYK, CFT, cold atoms, q-computing)"
Moderator: Ryan Thorngren (CMSA)

Time	Speaker	Title/Abstract
10:00 - 11:00am	Subir Sachdev	**Title:** Deconfined criticality in a random doped quantum Heisenberg magnet **Abstract:** We consider electrons with random and all-to-all hopping and Heisenberg spin exchange between sites with double electron occupancy prohibited. A perturbative renormalization group analysis yields a critical point with fractionalized excitations at a non-zero doping. The critical point is argued to separate a disordered Fermi liquid at higher doping, from a metallic spin glass at lower doping. We support our results by large M analysis of a model which extends the spin symmetry to SU(M). We note implications for optimal doping criticality in the cuprates.
11:00 - 11:30am	Hong Liu	**Title:** Bubble formation in operator growth, entanglement, and unitarity
11:30 - 12:00am	*Break*	
12:00 - 12:30pm	Xueda Wen	**Title:** Floquet conformal field theory and beyond **Abstract:** I will introduce an exactly solvable setup of a Floquet conformal field theory, i.e., a CFT under a time-dependent periodic driving. Physical properties including the phase diagram, correlation function, energy and entanglement evolution can be analytically obtained. I will also introduce generalizations of this setup to quasi-periodic driving, random driving, and so on.
12:30 - 1:00pm	Dries Sels	**Title:** Semiclassical echo dynamics in the SYK model **Abstract**: I'll discuss echo dynamics in the SYK model under effective time reversal in a semiclassical approach using the truncated Wigner approximation, which accounts for non-vanishing quantum fluctuations that are essential for the dynamics. We demonstrate that small imperfections introduced in the time-reversal procedure result in an exponential divergence from the perfect echo, which allows to identify a Lyapunov exponent. In particular, we find that this exponent agrees with that obtained from diagrammatic large-N expansion and is simply twice the Lyapunov exponent of the semiclassical equations of motion.

1:00 - 2:30pm *Lunch*

"Fracton, (sub-, higher- polynomial) symmetry and entangled matter"

Moderator: Ryohei Kobayashi (U Tokyo and CMSA)

2:30 - 3:30pm	Andrey Gromov	**Title:** Multipole gauge theories **Abstract:** I will start by reviewing what I know about higher rank gauge theories, vector symmetries and its applications to elasticity. Next I will generalize these ideas and introduce multipole symmetry and multipole gauge theories. Using this formalism I will describe a U(1) version of the Haah code.
3:30 - 4:00pm	*Break*	
4:00 - 4:30pm	Trithep Devakul	**Title:** Subsystem SPTs and Fracton Topological Order **Abstract:** Subsystem symmetry-protected topological (SSPT) phases are naturally related to models of fracton topological order by a generalized gauging duality. While the space of all fracton phases seems impossibly vast, the set of phases dual to particular SSPTs are a tractable subset. We discuss a natural classification of such SSPT phases and its implications for their dual fracton topological orders.
4:30 - 5:00pm	Yizhi You	**Title:** Fractonic Chern-Simons theory. **Abstract:** We investigate possible effective field theories for 3D fracton order, by presenting a general philosophy whereby topological-like actions for such higher-rank gauge fields can be constructed. Our approach draws inspiration from Chern-Simons and BF theories in 2+1 dimensions, and imposes constraints binding higher-rank gauge charge to higher-rank gauge flux. We show that the resulting fractonic Chern-Simons and BF theories reproduce many of the interesting features of their familiar 2D cousins. We analyze one example of the resulting fractonic Chern-Simons theory in detail, and show that upon quantization it realizes a gapped fracton order with quasiparticle excitations that are mobile only along a sub-set of 1-dimensional lines, and display a form of fractional self-statistics.
5:00 - 5:30pm	Juven Wang	**Title:** Higher-Rank Tensor Non-Abelian Gauge Field Theory of Fracton and Embeddon **Abstract:** The talk is based on https://arxiv.org/abs/1909.13879 and https://arxiv.org/abs/1911.01804. We introduce a new class of tensor gauge field theories in any dimension that is a hybrid class between symmetric higher-rank tensor gauge theory (i.e., higher-spin gauge theory) and anti-symmetric tensor topological field theory. Our theory describes a mixed unitary phase interplaying between gapless and gapped topological order phases. The "gauge structure" can be compact, continuous, and non-abelian. Our theory sits in territory beyond the familiar gauge theories - outside the paradigm of Maxwell electromagnetic theory in 1865 and Yang-Mills isospin/color theory in 1954. We also introduce a higher-moment polynomial degree-(m-1) global symmetry, acting on complex scalar/vector/tensor fields. We relate this higher-moment global symmetry of n-dimensional space, to a

		lower degree (either ordinary or higher-moment, e.g., degree-(m-1-ℓ)) subdimensional or subsystem global symmetry on layers of (n−ℓ)-submanifolds. These submanifolds are algebraic affine varieties (i.e., solutions of polynomials). The structure of layers of submanifolds as subvarieties can be studied via mathematical tools of embedding, foliation, and algebraic geometry. We explore the relation of these long-range entangled matters to a non-abelian generalization of Fracton order in condensed matter, a field theory formulation of foliation, the spacetime embedding, and the newly introduced Embeddon.

Wednesday, December 4

"Higher-energy, math, CFT, gravity, and quantum matter"

Moderator: Julio Parra Martinez (UCLA)

Time	Title	Abstract
8:30 - 9:00am	*Breakfast*	
9:00 - 10:00am	Xi Yin	
10:00 - 10:30am	Yifan Wang	**Title:** Fusion Category Symmetries and Anomalies in 1+1d
10:30 - 11:00am	*Break*	
11:00 - 11:30pm	Yuya Tanizaki	**Title:** Discrete anomaly matching in QCD **Abstract:** Recent renewed attention on anomaly matching elucidates new nonperturbative aspects of quantum field theories. Thanks to the discovery of generalization of global symmetry, we have a new class of anomaly that involves higher-form gauge fields. After a brief review of these developments, I would like to discuss its application for QCD with massless quarks. About QCD vacuum, we find a funny anomalous violation of baryon number symmetry, which excludes some exotic patterns of chiral symmetry breaking. We will also see that the same anomaly gives a nontrivial constraint in finite-temperature QCD phase diagram IF we introduce appropriate holonomy backgrounds, or imaginary chemical potential
11:30 - 12:00pm	Shang Liu	**Title:** Shift insulators: rotation-protected two-dimensional topological crystalline insulators **Abstract:** We study a two-dimensional tight-binding model of a topological crystalline insulator protected by rotation symmetry. The model is built by stacking two Chern insulators with opposite Chern numbers which transform under conjugate representations of the rotation group, e.g. p± orbitals. Despite its apparent similarity to the Kane-Mele model, it does not host stable gapless surface states. Nevertheless the model exhibits topological responses including the appearance of quantized fractional charge bound to rotational defects (disclinations) and the pumping of angular momentum in response to threading an elementary magnetic flux, which are described by a mutual Chern-Simons coupling between the electromagnetic gauge field and an effective gauge field corresponding to the rotation symmetry. We show that although the filled bands of the model do not admit a symmetric Wannier representation, this obstruction is removed on addition of appropriate atomic orbitals, which implies 'fragile' topology. As a result, the response of the model can be derived by representing it as a superposition of atomic orbitals with positive and negative integer coefficients.

12:00 - 2:30pm *Lunch*

"Quantum glass/non-Equilibrium/dynamics"

Moderator: Xueyang Song (Harvard)

2:30 - 3:30pm	Claudio Chamon	**Title:** Combinatorial gauge symmetry: a path to building quantum spin liquids in existing quantum hardware
3:30 - 4:00pm	Anushya Chandran	**Title:** Topological classes of quantum dynamics in quasi-periodically driven systems **Abstract:** Advances in the isolation and control of quantum systems has brought driven quantum phases into the laboratory. In periodically driven systems, new phases occur when the steady states, determined by Bloch-Floquet theorem, have novel spatio-temporal or topological order. In this talk I show how the Bloch-Floquet theorem is generalized to cases when the drives are quasi-periodic. I apply this framework to the simplest case of a few level system, and show that steady state dynamics admit a topological classification. When the classification is non-trivial the system exhibits a quantized pumping of energy, and a sensitivity to initial conditions, neither of which is present in the trivial case. I further discuss the stability of this classification, the behavior near the critical point where the topological class changes, and experimental results in diamond defect centers.
4:00 - 4:30pm	*Break*	
4:30 - 5:30pm	**Colloquium:** Xiao-Gang Wen	**Title:** Emergence of graviton-like excitations from a lattice model **Abstract:** I will review some construction of lattice rotor model which give rise to emergent photons and graviton-like excitations. The appearance of vector-like charge and symmetric tensor field may be related to gapless fracton phases.