Topological and Holographic Quantum Matter

Book of Abstracts

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HOLOGRAPHYCL

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Holography and its Applications to High Energy Physics, Quantum Gravity and Condensed Matter Systems

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Introduction

The Topological and Holographic Quantum Matter School and Conference is an event organized by the HolographyCL collaboration (ANID/ACT210100). Its purpose is to promote the interaction between researchers working in the areas of Condensed Matter and High Energy Physics and other related topics. Special focus is put on the training of future Latin American researchers.

Lecturers and speakers are recognized experts and leaders in their fields, making the event a highly valuable contribution to the local and international community.

For more information please visit holography.cl/thqm.

Program

	15/1 MONDAY	16/1 TUESDAY	17/1 WEDNESDAY
8:30 - 8:45	Registration		
8:45 - 9:00	Opening		
9:00 - 10:00	Eduardo Fradkin	Sankar Das Sarma	Nicolas Regnault
10:00 - 10:40	Karl Landsteiner	Paula Mellado	Joseph Maciejko
10:40 - 11:10	Coffee break	Coffee break	Coffee break
11:10 - 11:40	Bitan Roy	Blaise Goutéraux	Enrique Muñoz
11:40 - 12:10			David Abergel
12:10 - 12:50	Wladimir Benalcazar	Eric Bergshoeff	Alexander Tyner
12:50 - 14:30	Lunch	Lunch	Lunch
14:30 - 15:10	Ignacio Salazar Landea	Pedro Orellana	Free
15:10 - 15:50	Luis Rosales	Nicolás Grandi	
15:50 - 16:30	Ayan Mukhopadhyay	Marcello B. Silva Neto	
16:30 - 16:45	Coffee break	Poster session	
16:45 - 17:00	Dunkan Martínez		
17:00 - 17:15	Mario Solís		
17:15 - 17:30	Javier Moreno		
17:30 - 17:45	Mauro Cambiaso		

Abstracts - Day 1- January 15

Plenary talk: Theory of oblique topological insulators

Eduardo Fradkin
University of Illinois at Urbana-Champaign

A long-standing problem in the study of topological phases of matter has been to understand the types of fractional topological insulator (FTI) phases possible in 3+1 dimensions. Unlike ordinary topological insulators of free fermions, FTI phases are characterized by fractional Θ-angles, long-range entanglement, and fractionalization. Starting from a simple family of ZN lattice gauge theories due to Cardy and Rabinovici, we develop a class of FTI phases based on the physical mechanism of oblique confinement and the modern language of generalized global symmetries. We dub these phases oblique topological insulators. Oblique TIs arise when dyons—bound states of electric charges and monopoles—condense, leading to FTI phases characterized by topological order, emergent one-form symmetries, and gapped boundary states not realizable in 2+1-D alone. Based on the lattice gauge theory, we present continuum topological quantum field theories (TQFTs) for oblique TI phases involving fluctuating one-form and two-form gauge fields. We show explicitly that these TQFTs capture both the generalized global symmetries and topological orders seen in the lattice gauge theory. We also demonstrate that these theories exhibit a universal "generalized magnetoelectric effect" in the presence of two-form background gauge fields. Moreover, we characterize the possible boundary topological orders of oblique TIs, finding a new set of boundary states not studied previously for these kinds of TQFTs.

Pseudospectra of Holographic Quasinormal Modes

Karl Landsteiner
Instituto de Física Teórica UAM/CSIC

Quasinormal modes and frequencies are the eigenvectors and eigenvalues of a non-Hermitian differential operator. They are of crucial importance in the physics of black holes. The analysis of quasinormal modes in asymptotically Anti-de Sitter

geometries plays also a key role in the study of strongly coupled quantum many-body systems via gauge/gravity duality. In contrast to normal Sturm-Liouville operators, the eigenvalues of non-Hermitian (and non-normal) operators generally exhibit instability under small perturbations. After a brief review of quasinormal modes I will discuss the stability analysis of quasinormal frequencies for asymptotically planar AdS black holes based on pseudospectrum analysis. Specifically, I concentrate on the pseudospectra of scalar and transverse gauge fields, shedding light on their relevance within the framework of gauge/gravity duality.

Plenary talk: Non-Hermitian Dirac fermions: From band topology to Lorentz symmetry

Bitan Roy

Lehigh University

From the strongly coupled universe of quarks to the landscape of topological semiconductors, Dirac fermions offer a common universal language of unification. Furthermore, strongly interacting Dirac crystals is an ideal platform to showcase exotic quantum phase transition, critical phenomena, and emergence of non-Fermi liquids. In this talk, first I will outline universal model Hamiltonian for topological insulators and superconductors from any Altland-Zirnbauer symmetry class in any physical dimension and extend these notions to crystalline, higher-order and semimetallic phases, in terms of lattice-regularized Wilson-Dirac fermions. Once the stage is set, I will propose a simple but general non-Hermitian incarnation of all these phases that are devoid of any non-Hermitian skin effect. Such a phase of matter will be shown to feature real eigenvalue spectra and conventional bulk-boundary correspondences over an extended non-Hermitian parameter regime, where the bulk topological invariant can be measured from standard quantum Hall bar geometry, for example, in planar systems. Continuing the journey on the same avenue, in the second half of my talk, I will show how the space-time Lorentz symmetry can generically emerge in a family of interacting non-Hermitian Dirac crystals, when the underlying quasi-relativistic fermionic excitations interact with various bosonic degrees of freedom, such as spin-0 order-parameter fluctuations and spin-1 helical photons. Associated quantum critical phenomenon and the nature of the emergent marginal or non-Fermi liquids will be discussed. I will close the talk with a list of possible future directions and open problems.

Non-reciprocal solitary waves in periodic lattices

Wladimir Benalcazar

Emory University

In its standard form, the Ablowitz-Ladik model supports stable nonlinear localized eigenstates, i.e., solitons. In this talk, I will show that breaking parity in this model can either generate non-reciprocal linear instabilities on its static soliton states, or drive them into a self-induced non-reciprocal regime, in which the static soliton solutions cease to exist but, although still localized, ``solitary waves" propagate unidirectionally. These waves will eventually encounter one end of the lattice, where the only static soliton solution exists. I will discuss the topological origin of this mechanism in terms of winding numbers in the complex spectrum of the soliton's mean-field Hamiltonian and of its linear stability spectrum.

Entropic Theorem in General Spacetime Dimensions

Ignacio Salazar-Landea

Universidad Nacional de La Plata

We establish the irreversibility of renormalization group flows on a pointlike defect inserted in a d-dimensional Lorentzian conformal field theory. We identify the impurity entropy g with the quantum relative entropy comparing the deformed and undeformed theories on a null Cauchy surface. Positivity and monotonicity of the relative entropy imply that g decreases monotonically along renormalization group flows, and provides a clear information-theoretic meaning for this irreversibility.

Spin and Valley Filter Based on Two-Dimensional WSe2 Heterostructures

Luis Rosales

Universidad Técnica Federico Santa María

In this work we investigate the possibility of inducing and controlling spin and valley polarizations on different potential profiles of two-dimensional tungsten diselenide (WSe2) heterostructures. We study the case of single and double-potential barrier configurations. We focus on the resonant regime and how this effect allows the spin and valley polarizations. Exchange valley splitting is provided by the magnetic proximity effect, with the advantages that the splitting is dictated by the exchange interaction strength and that no applied magnetic field is required. This allows a convenient scenario for obtaining the tuning processes. Moreover, due to the versatility of being either positive or negative valued, this description opens up the possibility of tuning the valley splitting sign and magnitude together. Furthermore, we analyze the possibility of promoting valley and spin polarization inversions on transition metal dichalcogenides (TMDC) layers under the effects of time-dependent external potentials, such as time-oscillating gate voltages or laser irradiation. Different mechanisms are analyzed to synchronize the physical parameters of the proposed system, such as the Fermi energy, the frequency and amplitude of the time-dependent potential, and the external gate voltages, to optimize the time-dependent transport properties, such as the induced switching effects of the transport of the systems. These results validate the proposal of double quantum well structures of WSe2 as candidates to provide spin- and valley-dependent transport within an optimal geometrical parameter regime.

Strange metals and quantum black hole microstates

Ayan Mukhopadhyay

Pontificia Universidad Católica de Valparaíso

I will present an effective field theory (EFT) approach to strange metals in which carrier electrons hybridize with fermionic operators in holographic quantum dots spread over a lattice. In a large N limit, there is a small codimensional space of couplings in which strange metallic transport emerges from a universal scaling behavior of the spectral function and providing a refined picture of Planckian dissipation. It implies that one needs to fine tune only a very few parameters such as the ratio of two dimensionless effective irrelevant couplings to obtain linear in T resistivity over decades of temperatures. Remarkably there is no need to fine tune the critical exponent. The finite temperature spectral function fits experimental data well. I will argue that the physical mechanism of how the fine tuning is naturally realized can be learnt from the quantum information theory of black hole microstates which can be described by similar EFTs. In particular, I will discuss examples in which such a fine tuning is dynamically generated and is necessary to realize the black hole complementarity principle.

Anomalous Spin Textures in a 2D Topological Superconductor Induced by Point Impurities

Dunkan Martínez
Universidad Complutense de Madrid

Topological superconductors are foreseen as good candidates for the search of Majorana zero modes, where they appear as edge states and can be used for quantum computation. In this context, it becomes necessary to study the robustness and behavior of electron states in topological superconductors when a magnetic or non-magnetic impurity is present.

Generalization of Cardy formula to non-relativistic theories.

Mario Solis
Instituto Balseiro

Two dimensional conformal field theories have been extensively studied in the past. When considered on the torus, they are strongly constrained by modular invariance. However, introducing relevant deformations or chemical potentials pushes these theories away from criticality, where many of their aspects are still poorly understood. In this note we make a step towards filling this gap, by analyzing the theory of a Dirac fermion on the torus, deformed by a mass term and a chemical potential for the particle number symmetry. The theory breaks conformal and Lorentz invariance, and we study its spectrum and partition function. We also focus on two limits that are interesting on their own right: a massless relativistic fermion with nonzero chemical potential (a simple model for CFTs at finite density), and nonrelativistic Schrodinger fermions (of relevance in condensed matter systems). Taking inspiration from recent developments in massive modular forms, we obtain a representation of the torus free energy based on Fourier-transforming over a twisted boundary condition. This dual representation fullfills many properties analogous to modular invariance in CFTs. In particular, we use this result to derive Cardy-like formulas for the high energy density of states of these theories.

Conformal bounds from entanglement

Javier Moreno
Haifa U-Technion

The entanglement entropy of an arbitrary spacetime region A in a three-dimensional conformal field theory (CFT) contains a constant universal coefficient, $F(A)$. For general theories, the value of $F(A)$ is minimized when A is a round disk, F_0,and in that case it coincides with the Euclidean free energy on the sphere. I will present a new conjecture stating that for general CFTs, the quantity $F(A)/F_0$ is bounded above by the free scalar field result and below by the Maxwell field one. I will provide strong evidence in favor of this claim and argue that an analogous conjecture in the four-dimensional case is equivalent to the Hofman-Maldacena bounds. In three dimensions, our conjecture gives rise to similar bounds on the quotients of various constants characterizing the CFT. In particular, it implies that the quotient of the stress-tensor two-point function coefficient and the sphere free energy satisfies $C_T/F_0 ≤ 3/(4\pi \log2−6\zeta[3]) \simeq 0.14887$ for general CFTs. I will show that the bound is satisfied by free scalars and fermions, general $O(N)$ and Gross-Neveu models, holographic theories, $N=2$ Wess-Zumino models and general ABJM theories.

Exact TEM wave solution in cylindrical waveguides or fibers composed of topological insulators

Mauro Cambiaso
Universidad Andrés Bello

Using topological insulators to construct cylindrical waveguides we find transverse electromagnetic (TEM) field solutions that are forbidden with topologically trivial materials. These TEM field solutions attest to new evidence of the topological magnetoelectric effect in topological insulators. For example, we find a polarization rotation of an external electromagnetic field that differs from Faraday and/or Kerr rotations insofar our effect does not rely on a longitudinal magnetic field (with respect to the direction of propagation), the reflected field, or birefringence. Increasing the amount of coaxial cylindrical θ interfaces, we find another solution behaving as an optical fiber that confines exact transverse electromagnetic fields that propagate along the fiber with omnidirectional reflectivity. Also, considering a geometry with only one conducting outer wall and a single θ interface co-axial to the latter, a TEM solution is found that provides a concrete realization of a solution that evades Earnshaw's theorem.

Abstracts - Day 2 - January 16

Plenary talk: Nonabelian topological quantum matter and topological quantum computation

Sankar Das Sarma
University of Meryland

I will discuss and describe the current status on the search for Majorana zero modes to enable topological quantum computation.

Spin model for the Honeycomb NiPS3

Paula Mellado
Universidad Adolfo Ibáñez

In the Van der Waal material $\rm NiPS_3$, Ni atoms have spin S=1 and realize a honeycomb lattice. Six sulfur atoms surround each Ni and split their d manifold into three filled and two unfilled bands. Aimed to determine the spin Hamiltonian of $\rm NiPS_3$, we study its exchange mechanisms using a two-band half-filled Hubbard model. Hopping between d orbitals is mediated by p orbitals of sulfur and gives rise to bilinear and biquadratic spin couplings in the limit of strong electronic correlations. The microscopic model exposed a ferromagnetic biquadratic spin interaction $\rm K_1$ allowing the completion of a minimal $\rm J_1-J_3-K_1$ spin Hamiltonian for $\rm NiPS_3$. In bulk, a ferromagnetic first nearest neighbor $\rm J_1$ and a more significant antiferromagnetic third nearest neighbor spin coupling $\rm J_3$ agreed with the literature, while in monolayer $\rm J_1$ is positive and very small in comparison. Using a variational scheme, we found that a zig-zag antiferromagnetic order is the ground state of bulk samples. The zig-zag pattern is adjacent to commensurate and incommensurate spin spirals, which could hint at the puzzling results reported in $\rm NiPS_3$ monolayers.

Plenary talk: Charge transport without quasiparticles: lessons from hydrodynamics and gauge/gravity duality

Blaise Goutéraux
École Polytechnique

In this talk, I will summarize features of charge transport which may be gleaned from theoretical approaches which do not rely on an underlying quasiparticle description at low energies. More specifically, I will describe how hydrodynamics can be extended to account for approximate symmetries, such as slowly-relaxing momentum. I will discuss the interplay with gauge/gravity duality. If time permits, I will also discuss charge transport in (holographic) quantum critical phases.

Massive Modes in the Fractional Quantum Hall Effect

Eric Bergshoeff
University of Groningen

In this talk I will discuss a connection between (higher-spin) massive modes in the Fractional Quantum Hall effect, such as the GMP mode, and three-dimensional (one time and two space) relativistic higher-spin fields in quantum field theory.

Ghost-Fano Majorana effect in quantum dots

Pedro Orellana
Universidad Técnica Federico Santa María

We investigate the transport properties through a nanostructure composed of parallel double quantum dots coupled to two normal contacts. Each quantum dot is also connected to a topological superconducting nanowire, hosting Majorana zero modes at its ends. A magnetic flux threading across the area enclosed by the interferometer is considered. First, we investigate the physical quantities of the system employing Green's function formalism. We find that bound states emerge in symmetric configurations of topological superconducting nanowires, i.e., depending on their lengths and coupling energies to the quantum dots. Also, we find a transport suppression anomaly as a function of the magnetic flux in the same symmetric configurations mentioned above. Besides, we find that the magnetic flux controls both the projection of Majorana zero modes and the bound states in the continuum (Ghost-Fano Majorana effect) into the density of states and the linear conductance, suggesting that only by switching this parameter can we manipulate both bound states.

Exact solutions on the superconducting cylinder

Nicolás Grandi
Universidad Nacional de la Plata

I will present exact solutions of the field equations for a charged scalar, representing a superconducting perturbation that propagates on the surface of a cylinder. I will present exact solutions of the field equations for a charged scalar, representing a superconducting perturbation that propagates on the surface of a cylinder.

Magnetic control of wave packet rotation in three dimensional, mixed, multi-Weyl semimetals

Marcello B. Silva Neto
Universidade Federal do Rio de Janeiro

We investigate the topological phase transitions driven by band warping, λ, and a transverse magnetic field, B, for a three-dimensional, mixed, multi-Weyl semimetal. First, we use the Chern number as a tool to derive the $\lambda\times B$ phase diagram. Next, we relate all topological phases to the angular momentum of the rotating wave packet. Then, we show that a transverse magnetic field is able to manipulate the positions of the Weyl nodes, quenching the wave packet rotation, first partially and then completely, and finally leading to a sequence of field induced topological phase transitions. Finally, we turn to observable quantities and we calculate the magnetic field dependence of the current induced magnetization, as well as of the anomalous Hall conductivity. The current induced magnetization gaps the Weyl semimetal and one ends up with a Chern insulator. In this case, we find that both observables reflect the topological transitions associated to the wave packet rotation and can be used to identify the elusive 3D quantum anomalous Hall effect.

Abstracts - Day 3 - January 17

Plenary talk: Moiré Fractional Chern Insulators

Nicolas Regnault
Ecole Normale Superieure Paris, CNRS

TBA

Hyperbolic quantum matter

Joseph Maciejko
University of Alberta

Hyperbolic lattices are a new form of synthetic quantum matter in which particles effectively hop on a discrete tiling of two-dimensional hyperbolic space, a non-Euclidean space of negative curvature. Hyperbolic tilings were studied by the geometer H.S.M. Coxeter and popularized through art by M.C. Escher. Recent experiments in circuit quantum electrodynamics and electric circuit networks have demonstrated the coherent propagation of wave-like excitations on hyperbolic lattices. While the familiar band theory of solids adequately describes wave propagation through periodic media in Euclidean space, it is not clear how concepts like crystal momentum and Bloch waves can be extended to hyperbolic space. In this talk, I will discuss a generalization of Bloch band theory for hyperbolic lattices.

Electronic transport in Weyl semimetals with a uniform concentration of torsional dislocations

Enrique Muñoz
Pontificia Universidad Católica de Chile

Weyl semimetals constitute important examples of three-dimensional, gapless materials with non-trivial topological properties, as their band structure displays an even number of Weyl nodes. Near each node, the charge carriers are massless quasi-particles with linear dispersion and pseudo-relativistic properties. Each node is a monopolar source of Berry curvature, and hence they are protected from being gaped

since their topological charge (chirality) is a topological invariant. This rather idealized single-particle picture must however be revised under the presence of disorder and structural defects. In this talk, I will present an effective continuum model for a Weyl semimetal under the presence of a diluted uniform concentration of torsional dislocations, to calculate its thermal and thermoelectric transport coefficients. We model each dislocation as a cylindrical region of finite radius, where the corresponding elastic strain is described as a gauge field leading to a local pseudo-magnetic field. By a mathematical analysis for partial wave scattering (phase- shift) for the T-matrix, we obtain the corresponding retarded and advanced Green's functions that include the effects of multiple scattering events with the ensemble of randomly distributed dislocations. Combining this analysis with the Kubo formalism, and including vertex corrections, the transport coefficients are obtained by a combination of scattering theory, Green´s functions and the Kubo formulae in the linear response regime. We applied our theoretical results to predict the electrical and thermal conductivities, as well as the Seebeck coefficient for several transition metal monopnictides, i.e. TaAs, TaP, NbAs and NbP.

Inside Nature Physics

David Abergel
Nature Physics

TBA

Band topology beyond the ten-fold way

Alexander Tyner
NORDITA

The tenfold-way represents a cornerstone in topological classification of insulators based on non-spatial symmetries. Once thought to be exhaustive, it has been recently expanded to account for crystalline symmetries. I will discuss recent work towards the discovery and design of exceptions to this paradigm in solid-state materials and "engineered" systems respectively. In solid-state materials, identification of such exceptional systems is desirable due to the potential to identify large band gap topological insulators, however this poses a unique challenge as efficient symmetry indicator techniques fail by definition. A machine learning based protocol is presented to overcome this challenge and identify non-trivial topology in existing two-dimensional systems. A recipe for construction of exceptional topological phases in "engineered" systems is then presented. This recipe relies on a protocol of dimensional reduction of parent d+1-dimensional topological insulators to form d-dimensional projected topological branes.

List of participants

TBA

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