Friday, January 11, 2013
Speakers: Yi Li and Congjun Wu, University of California, San Diego
Title: Quaternionic analytic Landau levels in 3D and 4D

The usual 2D Landau levels arise from the cyclotron motion of electrons in magnetic fields which rely on the planar geometry. The nontrivial chirality in 2D is characterized by elegant complex holomorphic lowest Landau level wavefunctions which facilitate the study of fractional quantum Hall effects. On the other hand, the current study of 3D topological insulators is largely confined to lattice systems. The complicated Bloch-wave wavefunctions and dispersive energy spectra are an obstacle for the study of high dimensional fractional topological states.

We would like to go back to Landau levels for high dimensional topological states because they are explicit and elegant. We identify their connections to quaternions which are the first non-commutative division algebra discovered by Hamilton in 1843 and whose analytic properties were developed by Feuter. Simple Hamiltonians are constructed in the continuum by coupling spin-1/2 fermions with the SU(2) Aharanov-Casher potential. They exhibit flat SU(2) Landau levels in which orbital angular momentum and spin are coupled with a fixed helicity. The lowest Landau level wavefunctions satisfy the Cauchy-Riemann-Fueter condition of quaternionic analyticity. Each Landau level contributes one branch of gapless helical Dirac modes to the surface spectra. These results are also generalized to Dirac electrons, which can be viewed as a quaternionic generalization of the 2D Dirac Landau level problem. The zeroth Landau levels of Dirac fermions are a branch of half-fermion Jackiw-Rebbi modes which are degenerate over all the high dimensional angular momentum quantum numbers. We have also studied the 4D quantum Hall effects of the SU(2) Landau levels in the Landau-type gauge, which exhibit quantized non-linear electromagnetic response as a spatially separated chiral anomaly. We expect that the quaternionic analytical properties of Landau levels and the spectra flatness will further facilitate the study of high dimensional fractional topological states.

Refs:
1) Yi Li, Congjun Wu, Topological insulators with quaternionic analytic Landau levels, arXiv:1103.5422 .

2) Yi Li, Kenneth Intriligator, Yue Yu, and Congjun Wu, Isotropic Landau levels of Dirac fermions in high dimensions Phys. Rev. B 85, 085132 (2012)

3) Yi Li, Shou-Cheng Zhang, and Congjun Wu, Topological insulators with SU(2) Landau levels, arXiv:1208.1562.

Friday, January 25, 2013
Speaker: Stephen Minter, University of California, Merced
Title: Entanglement Between a Mesoscopic Quantum Mechanical Oscillator and the States of a Superconducting Flux Qubit

A mesoscopic superconducting particle is levitated using a stationary inhomogeneous magnetic field, and cooled to its mechanical ground state using sideband cooling from a nearby driver and pickup coil system driven slightly off-resonance. Any mechanical motion of the levitated particle will modulate the amount of flux passing through the pickup coil, which will be part of the superconducting flux qubit. If the driving frequency used is close to the difference of the frequency gap between the two qubit states and the mechanical frequency of the oscillator, entanglement between the motion states and the qubit states can occur. Subsequent time evolution can introduce a phase that affects the probability of measurement of the qubit being in the original state, a strong indicator of entanglement. Preliminary data of a fully macroscopic experiment to demonstrate sideband cooling will be presented.

Friday, February 8, 2013
Speaker: Rami Barends, University of California, Santa Barbara
Title: Long-lived coherence in superconducting quantum circuits
A viable quantum computer could solve complex mathematical problems in the fields of cryptography and large simulations which lie beyond the possibilities of present-day computers. Superconductivity is a strong candidate for quantum processing, because the electrons form a macroscopic quantum state. This allows for building large circuits on a chip. However, the superconducting quantum bits forget too fast. This so-called decoherence is one of the biggest obstacles to developing quantum computers.

At UCSB, we recently had a number of breakthroughs: We have developed a new type of superconducting transmon quantum bit: the "Xmon". It shows long coherence and allows for straightforward coupling to multiple elements, making it an ideal building block for a superconducting quantum integrated processor. We found that stray infrared light from the environment disturbs the superconductor, limiting coherence; we show how this influence can be fully removed by using multistage shielding. We found that Al on sapphire resonators are great quantum memories, having single-photon quality factors in excess of one million. All these breakthroughs allow us to build superconducting quantum circuits with coherence long enough for quantum error correction schemes.

Friday, February 15, 2013
Speaker: Igor Pikovski, University of Vienna
Title: Probing modifications of the canonical commutator in opto-mechanical systems
While the canonical commutation relation is one of the main cornerstones of quantum mechanics, in many theories of quantum gravity the commutator acquires a small modification. Here we show how modifications to the commutation relation of the center-of-mass mode of a massive mechanical oscillator can be probed using pulsed opto-mechanical systems. With the mass of the oscillator being close to the Planck mass, we show that certain quantum gravity

models that predict a deformation of the commutation relation can be tested. It thus opens a feasible route for table-top experiments to explore possible quantum gravitational phenomena.

Friday, February 22, 2013
Speaker: Simon Gröblacher, IQIM Postdoctoral Scholar in the Painter group
Title: Bell's inequality and beyond

Friday, April 5, 2013
Speaker: Shankar Iyer, Condensed Matter Theory
Title: Many-Body Localization in a Quasiperiodic System
Recent theoretical and numerical evidence suggests that localization can survive in disordered many-body systems with very high energy density, provided that interactions are sufficiently weak. Stronger interactions can destroy localization, leading to a so-called many-body localization transition. This dynamical phase transition is relevant to questions of thermalization in extended quantum systems far from the zero-temperature limit. It separates a many-body localized phase, in which localization prevents transport and thermalization, from a conducting ("ergodic") phase in which the usual assumptions of quantum statistical mechanics hold. Here, we present numerical evidence that many-body localization also occurs in models without disorder but rather a quasiperiodic potential. In one dimension, these systems already have a single-particle localization transition, and we show that this becomes a many-body localization transition upon the introduction of interactions. We also comment on possible relevance of our results to experimental studies of many-body dynamics of cold atoms and non-linear light in quasiperiodic potentials.

Friday, April 12, 2013
Speaker: Robert Prevedel, Senior Post-Doctoral Fellow at the Research Institute for Molecular Pathology (IMP) and Max F. Perutz Laboratories GmbH (MFPL), Vienna, Austria
Title: Experimental investigation of the uncertainty principle using entangled photons
The uncertainty principle, first formulated by Heisenberg, provides a fundamental limitation on an observer's ability to simultaneously predict the outcome when one of two measurements is performed on a quantum system. However, if the observer has access to a particle which is entangled with the system, his uncertainty is generally reduced: indeed, if the particle and system are maximally entangled, the observer can predict the outcome of both measurements precisely. This effect has recently been quantified by Berta et al. (Nat. Physics 6, 659 (2010)) in a new, more general uncertainty relation. Here we perform experiments to probe the validity of this new inequality using entangled photon pairs. The behavior we find agrees with the predictions of quantum theory, satisfying the new uncertainty relation. An optical delay line that serves as a quantum memory, in combination with fast feed-forward allows an observer to gain more information and hence lower uncertainty about the outcome of an measurement than would be possible without the entangled particle. This shows not only that the reduction in uncertainty caused by entanglement can be significant in practice, but also demonstrates the use of the inequality to witness entanglement.

Friday, April 19, 2013
Speaker: Peter Brooks, Theory group/IQI
Title: Quantum Computing with asymmetric Bacon-Shor codes

Typical fault-tolerant quantum circuits are designed to work effectively against generic noise without any special structure. But in some physical settings, the noise is expected to be highly biased, with dephasing in the computational basis far more likely than bit flips. I will present a scheme for fault-tolerant quantum computation based on asymmetric Bacon-Shor codes, which works effectively against highly biased noise dominated by dephasing. We find the optimal Bacon-Shor block size as a function of the noise strength and the noise bias, and estimate the logical error rate and overhead cost achieved by this optimal code. Our fault-tolerant gadgets, based on gate teleportation, are well suited for hardware platforms with geometrically local gates in two dimensions.

Friday, May 3, 2013
Speaker: Katja C. Nowack, Postdoctoral Scholar in the Moler lab, Stanford University
Title: Imaging currents in HgTe quantum wells in the quantum spin Hall regime

Conducting edge channels at the sample boundaries are a key feature of the quantum spin Hall (QSH) state, which was predicted [1] and experimentally demonstrated [2] to be realized in HgTe quantum wells. The existence of the edge channels has been inferred from transport measurements on sufficiently small devices, which find local [2] and non-local [3] conductance values close to the quantized values expected for ballistic edge channels and recently signatures of the spin polarization [4]. Here we directly confirm the existence of the edge channels by imaging the magnetic fields produced by current flowing in large Hall bars made from HgTe quantum wells using a scanning superconducting interference device (SQUID). From the magnetic images we reconstruct the current density in the device with several micron spatial resolution. These images distinguish between current that passes through each edge and the bulk. Upon tuning the bulk conductivity by gating or raising the temperature, we observe a regime in which the edge channels clearly coexist with the conducting bulk, providing input to the question of how ballistic transport may be limited in the edge channels. Our results represent a versatile method for characterization of new quantum spin Hall materials systems.

[1] B. A. Bernevig, T. L. Hughes & S. C. Zhang, Science 314, 1757-1761 (2006) [2] M. Koenig et al., Science 318, 766-770 (2007) [3] A. Roth et al., Science 325, 294-297 (2009) [4] C. Brüne et al., Nature Physics 8, 485-490 (2012)

Friday, May 10, 2013
Speaker: Tom Alberts, Scott Russell Johnson Senior Research Fellow in Mathematics; Lecturer in Mathematics
Title: An Introduction to the Schramm-Loewner Evolution

Schramm-Loewner Evolution is a one-parameter family of random curves that can be used to describe the random geometry of many two-dimensional lattice models at criticality, for example percolation, Ising, loop-erased random walk, the uniform spanning tree. Its invention and subsequent study over the last 15 years has led to methods for calculating and computing various critical exponents arising in these models, using classical techniques from probability theory and stochastic calculus. I will give some basic examples of how this can be done for some of the well known models like percolation and loop-erased walk. It is conjectured that some variants of SLE can also be used to understand critical exponents for various phenomenon in quantum mechanics, for example the quantum Hall effect. Time permitting I will attempt to overview some of these conjectured connections.

Friday, May 17, 2013
Speaker: Pol Forn-Diaz, Postdoctoral Scholar in the Kimble Group
Title: An on-chip atom-photon interface using photonic nanostructures
Control of single atoms in optical cavities has attained exquisite levels of precision as demonstrated in several groundbreaking experiments in the last two decades. However, realizing complex quantum information science protocols would require a network of several light-matter interfaces, necessitating a scalable cavity architecture. Novel lithographically fabricated devices have recently been developed to this end, such as photonic crystal cavities, whose optical properties allow cavity QED experiments with cold atoms to be performed on a chip. In this talk I will describe our efforts to position and detect a cloud of cold cesium atoms near the surface of an optical waveguide that contains a photonic crystal cavity at its end. I will also describe the advantages offered by this system with respect to previous architectures and its potential applications.

Friday, May 24, 2013
Speaker: Steven Anton, graduate student from John Clarke's group at Berkeley
Title: Magnetic flux 1/f noise in SQUIDs and qubits
Noise processes with spectral densities scaling inversely with frequency (1/f noise) are as ubiquitous as they are diverse in origin. One particular noise process, magnetic flux 1/f noise, degrades the low-frequency performance of SQUIDs, which are used as exquisitely sensitive detectors in a wide range of applications. More recently, flux noise has been shown to be a dominant source of decoherence in flux-sensitive superconducting qubits. Reducing flux noise, therefore, has become a crucial step in the development of quantum computing using superconducting circuits. To shed light on this poorly understood noise source, our group has made extensive measurements of flux noise in over 150 SQUIDs, characterizing the dependence of the noise on temperature as well as other properties. We show our results to be overwhelmingly incompatible with the existing theoretical model of independently fluctuating electrons, which implies significant and complex interactions between fluctuators. We also show a systematic reduction in flux noise with the addition of capping materials applied to the surface of the superconductor. Finally, we conclude that developing a comprehensive theoretical understanding is critical to significantly reducing flux noise.
[1] http://physics.berkeley.edu/research/clarke/Publications/PhysRevLett.110.147002

Friday, May 24, 2013
Speaker: Mingwu Lu, Lev Lab Stanford University
Title: Quantum degenerate dipolar gases of dysprosium, in Bose and Fermi flavor
Advancing quantum manipulations of ultracold atomic gases are opening a new frontier in the quest to better understand strongly correlated matter. By exploiting the long-range and

anisotropic character of the dipole-dipole interaction, we hope to create novel forms of soft quantum matter, phases intermediate between canonical states of order and disorder. Our group recently created Bose and Fermi quantum degenerate gases [1,2] of the most magnetic element, dysprosium, which should allow investigations of quantum liquid crystals. We present details of recent experiments that created the first degenerate dipolar Fermi gas as well as the first strongly dipolar Bose-Einstein condensation (BEC) in low fields. Paticularly we demonstrated first time the direct evaporative cooling of single component ultracold fermions to Fermi degeneracy. For bosonic isotopes, BECs of Dy will form the key ingredient in novel scanning probes using atom chips. We are developing a Dy cryogenic atom chip microscope that will possess unsurpassed combination of sensitivity and resolution for the imaging of condensed matter materials exhibiting topologically protected transport and magnetism.

[1]M. Lu, N. Burdick, and B. Lev, Quantum Degenerate Dipolar Fermi Gas, Physical Review Letters 108, 215301 (2012)

[2]M. Lu, N. Burdick, and B. Lev, Strongly Dipolar Bose-Einstein Condensate of Dysprosium, Physical Review Letters 107, 190401 (2011)

Friday, May 31, 2013
Speaker: Dr. Ulrich Schneider, Ludwig Maximilian University - Munich, Germany
Title: Negative absolute temperatures and the formation of superfluid order
Absolute temperature, that is the fundamental temperature scale in thermodynamics, is usually bound to be positive. Under special conditions, however, negative absolute temperatures can be possible. In this talk, I will present the first negative temperature state for motional degrees of freedom: By use of an optical lattice we could create an ensemble of ultracold bosons in which the states with the highest kinetic energy are most occupied. This state is stable for arbitrary atom numbers, even for strong attractive interactions.

Negative temperatures imply negative absolute pressures and open up new parameter regimes for ultracold atoms, enabling fundamentally new many-body states and counterintuitive effects such as Carnot engines with above-unity efficiency.

In addition, this system enabled us to study the dynamics of the phase transition from Mott insulator to superfluid and to experimentally investigate how fast phase coherence can spread.

Friday, June 7, 2013
Speaker: Matt Kelley, Postdoctoral Scholar in Geochemistry
Title: "Controlling Molecular Motion and State using Terahertz Time Domain Techniques"
Terahertz time-domain spectroscopy (THz-TDS) is a now well established method of acquiring the low-resolution far infrared, spectrum of materials. In THz-TDS, an ultrafast laser is used to generate a sub- to few- cycle THz pulse via various methods including optical rectification or two-color laser induced plasma. The electric field is often directly sensed by electro-optic detection. The application of high field strength pulses to samples can create non-linear interactions in materials, allowing for coherent control of populations via ladder climbing or other interactions which depend on the sub-single-cycle nature of the pulses. The spectrum of

several amino acid and sugar microcrystals were acquired by THz-TDS in the Blake group and will be the subject of further high-field experiments in the future.

Friday, June 14, 2013
Speaker: Darius Torchinsky, Postdoctoral Scholar in the Hsieh Group
Darius Torchinsky will discuss his work on high-Tc superconductors

Friday, September 6, 2013
Speaker: Justin Song, Harvard/MIT
Title: "Interactions at the Dirac point in Graphene Heterostructures"
While the vanishing density of states and Fermi velocity renormalization in single layer graphene render interaction effects unimportant close to the Dirac point, heterostructures comprised of graphene layers tell a very different story. I will discuss how interactions can play an unexpected role in the behavior of graphene heterostructures. One such example occurs in graphene-hBN (hexa-Boron Nitride) heterostructures which form an in-plane superlattice. Interacting Dirac particles respond more strongly to a sub-lattice `colored' potential (asymmetric) than to a sub-lattice `blind' potential. As a result, many-body effects lead to a giant enhancement of the sub-lattice `colored' potential that can give a large and non-vanishing gap at the Dirac point (as high as room temperature). Another example, occurs in double layer graphene heterostructures where the graphene layers are electrically insulated from each other. When the two layers are tuned to charge neutrality, a new mechanism for Coulomb drag manifests. This new mechanism occurs when fast interlayer energy relaxation mediated by the Coulomb interaction couples the charge current flow in both layers to give a large Coulomb drag response that approaches a "universal" value (insensitive to interaction strength). Interestingly, the same mechanism gives rise to a giant and non-vanishing Hall drag in the presence of a magnetic field, unanticipated by earlier theories of drag.

Friday, September 27, 2013
Speaker: Haixing Miao, Chen group
Title: "Quantum filtering in continuous quantum measurements"
When using a continuous quantum field to probe a quantum system of interest, we normally introduce some auxiliary degrees of freedom to mediate the interaction between the probe field and the quantum system, e.g., the cavity modes in typical cavity QED systems. They not only modify the effective interaction strength, but also filter the information of the quantum system that is accessible by the probe field.

We therefore call them quantum filters. In the first part of my talk, I will discuss how the presence of quantum filters influences the evolution of the quantum system, in particular, the conditional dynamics under a continuous measurement of the probe field. In the second part of my talk, I will discuss applications of these quantum filters in enhancing the sensitivity of measuring classical signals that are coupled to the quantum system, e.g., in the case of quantum-limited gravitational-wave detectors.