Christopher L. Henley Symposium

Cornell University

September 12, 2014
401 Physical Sciences Building

Program

8:30 Refreshments & Registration

8:50 Opening Remarks
Veit Elser, Cornell University

9:00 Frustration
Chair: Veit Elser, Cornell University

9:00 Michel Gingras, University of Waterloo and Canadian Institute for Advanced Research
Has Compelling Experimental Evidence for Order-by-Disorder at Last Been Found in a Frustrated Magnetic Material?

9:30 Collin Broholm, The Johns Hopkins University
Neutron Scattering from Corner-sharing Simplexes

10:00 David Huse, Princeton University
Order by disorder in spin glasses

10:30 Break

11:00 Quasicrystals
Chair: Mike Widom, Carnegie Mellon University

11:00 Marc de Boissieu, Université de Grenoble, Science et Ingénierie des Matériaux et Procédés
Quasicrystals: structure and dynamics

11:30 Marek Mihalkovic, Slovak Academy of Science
Canonical-cell tiling and real icosahedral structures

12:00 Ron Lifshitz, Tel Aviv University
Mesoscopic Quasicrystals

12:30 Lunch in Baker Portico *
(1st floor atrium by Baker Hall)

1:30 Interacting electrons and numerical methods
Chair: Jan von Delft, University of Munich

1:30 Bert Halperin, Harvard University
Fractional quantized Hall effect and phase transitions in the lowest Landau level of monolayer graphene

2:00 Siew-Ann Cheong, Nanyang Technological University
Numerical Methods as Exploration Tools for Theoretical Condensed Matter Physics

2:30 Hitesh Changlani, University of Illinois at Urbana-Champaign
Density matrix based numerical method for discovering order in interacting systems

3:00 Anders Sandvik, Boston University
Low-energy excitations in percolating quantum spins

3:30 Break

4:00 Biological physics
Chair: Chen Zeng, George Washington University

4:00 Jane Kondev, HHMI and Brandeis University
DNA folding in cells

4:30 Rob Phillips, California Institute of Technology
How Viruses Make New Viruses: A Single-Molecule View

5:00 Robijn Bruinsma, University of California at Los Angeles
DNA confinement drives uncoating of the HIV Virus

6:00 Banquet in Baker Portico *
(1st floor atrium by Baker Hall)

*Meals are for registered attendees only.
Frustration

Michel Gingras

University of Waterloo and Canadian Institute for Advanced Research

Has Compelling Experimental Evidence for Order-by-Disorder at Last Been Found in a Frustrated Magnetic Material?

Abstract: In some magnetic systems, known as frustrated magnets, the lattice geometry or the competition between different spin-spin interactions can lead to a sub-exponentially large number of accidentally degenerate classical ground states. Order-by-disorder (ObD) is a concept of central importance in the field of frustrated magnetism and to which Chris Henley made significant contributions in the late 1980s and early 1990s.

Saddled with large accidental degeneracies, a subset of states, those that support the largest quantum and/or thermal fluctuations, may be selected to form true long-range order. ObD has been discussed extensively on the theoretical front for over 30 years and proposed to be at play in a number of experimental settings.

Unfortunately, convincing demonstrations of ObD in real materials have remained scarce. In this talk, I will review the phenomena of thermal and quantum of order-by-disorder, mention the singular contributions Chris made to our understanding of ObD and, finally, discuss how recent work may have evinced compelling evidence for ObD in some frustrated XY pyrochlore antiferromagnetic materials.
Frustration

Collin Broholm

The Johns Hopkins University

Neutron Scattering from Corner-sharing Simplexes

Abstract: I shall discuss the unusual magnetism of spins on the vertices of corner-sharing simplexes. Structures of interest include the pyrochlore, triangular, and kagome lattices and variants thereof. To understand the absence of forward elastic scattering in SrCr9pGa12-9pO19, the diffuse scattering in ZnCr2O4, and emergent quasiparticles in Pr2Zr2O7 and Herbertsmithite, the work of Chris Henley and discussions with him in Baltimore always provide essential insights and inspiration.
Frustration

David Huse

Princeton University

Order by disorder in spin glasses

Abstract: The phenomenon of “order by disorder” occurs in systems with highly degenerate ground states, when among the ground states those that are ordered have higher entropy than those that are disordered. Chris Henley made many important contributions to this subject for geometrically frustrated magnets. A similar story happens for +/-J Ising spin glasses, as has been realized only rather recently. I will discuss our results for the two-dimensional case (Thomas, Huse and Middleton, PRL 107, 047203 (2011)).
Quasicrystals

Marc de Boissieu

Université de Grenoble, Science et Ingénierie des Matériaux et Procédés

Quasicrystals: structure and dynamics

**Abstract:** The discovery of quasicrystals in 1982 by Dan Shechtman, has been a breakthrough in crystallography which led to a paradigm shift and has deeply modified our understanding of long range ordered materials. Indeed, quasicrystals are materials which are long range ordered but without periodicity: their diffraction pattern presents sharp Bragg peaks but with symmetries, such as five-fold rotation axes, incompatible with lattice translation. After an introduction on quasicrystals, recent results on their atomic structure in the binary icosahedral CdYb quasicrystal system will be presented. The structure of the quasicrystal is now well understood, and atomic scale simulations are at hand.

Quasicrystals

Marek Mihalkovic
Slovak Academy of Science

Canonical-cell tiling and real icosahedral structures

As opposed to 6D hyperspace description of icosahedral quasicrystal structures, canonical-cell tiling (CCT) (Henley, 1991) was designed from purely local cluster-packing considerations, combining linking constraints with packing efficiency argument into a set of four fundamental cells. While none of the existing icosahedral quasicrystal structures derived from diffraction refinements is truly consistent with CCT geometry, all of the existing refinements of “approximants” - crystalline phases closely related to quasicrystals – are identified as proper CCT networks of icosahedral clusters. I discuss this controversy for all three major classes of icosahedral quasicrystals, and update the status of long-standing question: do we know atomic positions in a quasicrystal?
Quasicrystals

Ron Lifshitz

Raymond & Beverly Sackler School of Physics & Astronomy, Tel Aviv University

Mesoscopic Quasicrystals

Abstract: Most of the research on quasicrystals, since their discovery over three decades ago, has concentrated on the study of solid-state quasicrystals in the form of inter-metallic alloys. In my talk I shall focus on quasicrystals composed of building blocks whose dimensions are on a mesoscopic scale of tens to thousands of nanometers. These range from artificially constructed metamaterials, such as photonic quasicrystals, to self-assembled soft-matter quasicrystals[1-3]. In addition to having promising applications, especially in the optical domain, these materials give us the opportunity to study quasicrystals in ways that were impossible before. As time permits, I shall discuss a few aspects of our work on these systems, ranging from our recent explanation of the stability of certain quasicrystals composed of soft isotropic particles [4,5], and our numerical discovery of "cluster quasicrystals" [6], to the design of nonlinear photonic quasicrystals for optical frequency conversion [7].

Interacting electrons and numerical methods

Bertrand I. Halperin

Harvard University

Fractional quantized Hall effect and phase transitions in the lowest Landau level of monolayer graphene.

Abstract: Many fractional quantized Hall states have been seen in the zeroth Landau level of graphene (i.e., in the range \(-2 < \nu < 2\)), but there are striking differences between the wings of the Landau level (\(|\nu| > 1\)) and the center portion (\(|\nu| < 1\)). In the outer portion, fractions with odd numerator seem to be missing. In the inner portion, fractions with even and odd numerators are seen, and experiments at Harvard also see phase transitions, as a function of magnetic field or electron density, at fixed filling fraction. We argue that these differences can be largely understood as a consequence of the effects of interaction terms in the Hamiltonian that violate SU(2) valley symmetry, which act differently in the wings and in the center of the Landau level. Missing fractions may be a consequence of low-energy Skyrmions.

Siew-Ann Cheong

Division of Physics and Applied Physics, School of Physical and Mathematical Sciences Nanyang Technological University

Numerical Methods as Exploration Tools for Theoretical Condensed Matter Physics

Abstract: It was no accident that out of the five papers I published with Chris as I worked towards my PhD, three reported analytical results. I think this is how Chris likes to think about problems in theoretical condensed matter physics: using various methods to open
windows of insight into such problems. Numerical methods were no exception: numerical outputs generated by simple codes would lead me in unexpected ways to exact solutions and scaling relations. In this talk, I would share these three journeys that shaped how I now think as a physicist. First, I would describe a numerical procedure for calculating the many-body fermion density matrix to a block of sites within an infinite chain, in terms of the ground-state expectations of products of projection operators. I then show regularities that appear in the numerical results, when these ground-state expectations are computed in the one-dimensional Fermi sea. Adapting an analytical method in a paper [1] that appeared a few years before we obtained the numerical results, we then worked out an exact formula for the many-body fermion density matrix [2]. This exact formula allowed us to write the eigenvalues of the density matrix in terms of exponentials of pseudo-energies of a non-interacting system of fermions, and thus allowed us to compute the eigenvalues for very large block sizes. Again, numerical regularities appeared when we plot the spectra of different block sizes, which led us to suspect, and thereafter work out a scaling relation for the pseudo-energies [3]. Finally, I would talk about the numerical methods to compute the many-body fermion density matrix of two distant blocks in an infinite chain [4]. To demonstrate the utility of such a density matrix, we worked with the exactly diagonalized ground states of fermion chains with infinite nearest-neighbor repulsion. Again, we discovered numerical regularities in the many-body ground-state wave function. Chris immediately realized that the $P$-particle ground state of a chain of length $L$ with infinite nearest-neighbor repulsion can be mapped to the $P$-particle ground state of a chain of length $L' = L - P$ with zero nearest-neighbor repulsion. I very quickly verified that this mapping is exact, and moved on to write the ground-state expectation of nonlocal operator products (like the two-point function) on the chain with infinite nearest-neighbor repulsion as an intervening particle expansion of ground-state expectations of a series of nonlocal operator products that can be explicitly constructed on the chain with zero nearest-neighbor repulsion [5]. If time permits, I would describe how we used this exact mapping to investigate finite-size effects resulting from different boundary conditions [6].

Interacting electrons and numerical methods

Hitesh Changlani

University of Illinois at Urbana-Champaign

Density matrix based numerical method for discovering order in interacting systems

Abstract: As part of my graduate research with Professor Chris Henley, I ventured into understanding the low energy physics of randomly diluted antiferromagnets at the percolation threshold [1]. In this talk I will summarize the key ideas we developed during this work to provide a context for the general themes that emerged from this study. In particular, I will show how one can process numerical information from low-lying "quasidegenerate states" (QD) in a manner that reveals the underlying low energy degrees of freedom. This is done with a quasidegenerate density matrix (QDDM), a mathematical construct involving diagonal and off-diagonal density matrices (those between all pairs of QD states). I will conclude by providing representative examples, in which numerical data from accurate many-body calculations was used to reveal the underlying order parameter and to detect a quantum phase transition [2].

Interacting electrons and numerical methods

Anders W Sandvik

Boston University

Low-energy excitations in percolating quantum spins

Abstract: When the 2D square-lattice S=1/2 Heisenberg antiferromagnet is randomly diluted with non-magnetic impurities, the long-range order is lost only at the classical percolation point. The percolating cluster possesses long-range order although it has vanishing stiffness, as is the case also in the corresponding classical system. However, the excitations of the quantum system have distinct non-classical features, due to the formation of almost localized moments in regions of the cluster where there is sublattice imbalance (excess of sites belonging to one of the sublattices). These excitations were discovered and detected using exact diagonalization of small clusters as well as quantum Monte Carlo simulations of larger systems. I will discuss some aspects of this work.
Biological physics

Jane Kondev

Howard Hughes Medical Institute and Brandeis University

DNA folding in cells

Abstract: The length of DNA in a living cell exceeds the linear size of the volume it occupies by three or more orders of magnitude. Therefore, for DNA to fit inside a cell it must be folded up. Experimental techniques based on fluorescence imaging and DNA sequencing have begun to quantitatively characterize the folded state of DNA in cells, revealing mathematical rules that can be understood in the context of simple physics models. In this talk I will describe the emerging experimental and theoretical landscape of DNA folding in cells, and discuss how cells might control the folded state of DNA so as to regulate its biological functions such as recombination and transcription.
Abstract: One of the most beautiful and interesting meeting places of geometry, biology and physics is the study of viruses. Using single-molecule techniques, it has become possible to examine viruses both while they package and eject their DNA. This talk will begin with simple physical arguments about the forces that attend viral DNA packaging and ejection as well as the resulting time scales for such ejection. Using these predictions as motivation, I will describe single-molecule experiments designed to watch the ejection process one virus at a time both in vitro and in vivo. In both settings, the results provide challenges to current theoretical interpretations of the ejection process and build upon many of the scientific themes that have been central to the career of Prof. Chris Henley.
DNA confinement drives uncoating of the HIV Virus

Abstract: The capsid that protects the genome molecule(s) of a virus is in general quite robust against mechanical stress. An outstanding exception is the mature capsid of retroviruses, such as HIV. We present a description of the mature HIV capsid where a key function is not the mechanical protection of the genome but instead a role as a "reactor vessel" for the action of the enzyme reverse transcriptase that converts single-stranded RNA molecules into double-stranded DNA molecules inside mature HIV viral capsids. The uncoating of the HIV virus is determined by the fracture force exerted on the capsid wall by the DNA torus that is produced by the reverse transcriptase.