Perspectives in Mathematical Physics
Perspectives en physique mathématique
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FERENC BALOGH, Concordia University and CRM
Reduction of planar orthogonality to non-hermitian orthogonality on contours

The asymptotic behaviour of orthogonal polynomials associated with measures supported in the whole complex plane is of essential importance in obtaining various limiting spectral statistics for certain non-hermitian random matrix models. The standard tools to analyse the asymptotics for orthogonal polynomials on the real line or on a complex contour, including the celebrated Riemann-Hilbert method, are not readily avaliable in the planar setting.

For certain special measures, however, the two-dimensional hermitian orthogonality relations can be shown to be equivalent to a set of non-hermitian orthogonality relations with respect to an analytic weight function integrated on a combination of contours in the complex plane. This reduction amounts to solving a family of d-bar problems and, in certain cases, it simplifies the asymptotic analysis considerably since it allows the the Riemann-Hilbert approach to obtain strong asymptotics for the corresponding orthogonal polynomials. The method will be illustrated on an example based on a joint work with M. Bertola, S.Y. Lee and K. McLaughlin.

VINCENT BOUCHARD, University of Alberta
The (un)reasonable effectiveness of string theory in mathematics

In recent decades, an impressive number of fascinating results (many of them still conjectural) in various areas of mathematics, such as geometry, topology and number theory, have been obtained via string theory and its dualities. In this talk, I will focus on a new mysterious recursive structure that appears to unify seemingly unrelated counting problems in geometry, with far-reaching and mostly unexplored consequences. We conjectured this new structure through a careful study of topological string theory and mirror symmetry, putting to work "the (un)reasonable effectiveness of string theory in mathematics".

TIAGO DINIS DA FONSECA, Centre de recherches mathématiques
Higher spin 6-Vertex model and Macdonald polynomials

It is known that the 6-Vertex model is a quantum integrable model, therefore we know, at least in theory, everything about it. For example, in the case of Domain Wall Boundary Conditions, the partition function is a relatively simple determinant (Izergin, 1987) and it is related to a Schur polynomial.

In a more recent work, Caradoc, Foda and Kitanine (2006) tell us how to generalize this result for higher spins. Based in their work, one can prove that the new partition function is related to a Macdonald polynomial (dF and Balogh, to appear).

In this talk, I will describe the 6-vertex model, explain how to create the higher spin model from the original model. And finally, I will sketch how one can prove that this is indeed a Macdonald polynomial.

PATRICK DESROSIERS, IMAFI, Universidad de Talca
Beta-ensembles of random matrices

Most models in Random Matrix Theory are solved by using techniques that depend on their symmetry properties. In the last two decades, however, general families of matrix models that provide a unifying framework for random matrices have been developed; they are called the beta-ensembles. In this talk, I will briefly introduce these ensembles and review recent advances. The presentation will focus on the interrelationships between beta-ensembles, stochastic differential equations, and remarkable special functions in many variables, such as Jack polynomials.

DAVID FEDER, University of Calgary
Graph Theory in Quantum Many-Body Physics

The Hamiltonian for bosonic and fermionic particles hopping on lattices can be interpreted as the adjacency matrix of an undirected and generally weighted graph. The properties of these quantum many-body systems can therefore be analyzed in terms of graph theory. For example, the simple graph for non-interacting distinguishable particles is the Cartesian product of each particle's adjacency matrix; if these particles become indistinguishable, the graph collapses via a graph equitable partition. In the presence of strong interactions between the particles, the graphs are generally decomposable as weak products (i.e. they are the Kronecker products of adjacency matrices). Under various circumstances, these techniques can allow for the efficient calculation of the eigenstates (and therefore the properties) of physically interesting quantum many-body systems.

DANIEL GOTTESMAN, Perimeter Institute for Theoretical Physics
Quantum Error Correction

As logic circuits become smaller and smaller, it makes sense to consider what happens once they become so small they start to behave according to quantum mechanics. What we get is a quantum computer, for which the state can be described as a vector in a finite-dimensional Hilbert space. Quantum computers offer the possibility of some dramatic computational speedups, the most famous being Shor's factoring algorithm. However, quantum states are very delicate, and we won't be able to realize the benefits of quantum computation without a way to correct errors. I will describe how to create quantum error-correcting codes which can protect even very large quantum states against noise and decoherence. The key to understanding a quantum error-correcting code lies in the stabilizer, a finite group encapsulating many of the symmetries of the code.

GABOR KUNSTATTER, University of Winnipeg
Quantum mechanics on the discretized half-line

We investigate nonrelativistic quantum mechanics on the discretized half-line, constructing a one-parameter family of Hamiltonians that are analogous to the Robin family of boundary conditions in continuum half-line quantum mechanics. For classically singular Hamiltonians, the construction provides a singularity avoidance mechanism that has qualitative similarities with singularity avoidance encountered in loop quantum gravity. Applications include the free particle, the attractive Coulomb potential, the scale invariant potential and a black hole described in terms of the Einstein-Rosen wormhole throat. The spectrum is analyzed by analytic and numerical techniques. In the continuum limit, the full Robin family of boundary conditions can be recovered via a suitable fine-tuning but the Dirichlet-type boundary condition emerges as generic.

RAYMOND LAFLAMME, Institute for Quantum Computing, UWaterloo
Quantum Error Correction: from theory to practice

The Achilles' heel of quantum information processors is the fragility of quantum states and processes. Without a method to control imperfection and imprecision of quantum devices, the probability that a quantum computation succeed will decrease exponentially in the number of gates it requires. In the last fifteen years, building on the discovery of quantum error correction, accuracy threshold theorems were proved showing that errors can be controlled using a reasonable amount of resources as long as the error rate is smaller than a certain threshold. We thus have a scalable theory describing how to control quantum systems. I will describe a variety of mathematical techniques that have been developed to turn this theorem into a useful tool in the laboratory and will sum up with a quick overview of where we are at controlling quantum systems in practice.

JOSH LAPAN, McGill University
Black Hole Greybody Factors and Monodromies

Black hole thermal radiation has captivated part of the theoretical physics community since its discovery by Hawking. In light of holography, deep connections have emerged between details of the black hole and a holographically dual field theory. Recent observations demonstrate that for a large class of black holes — as well as five-dimensional black rings and black strings — the product of inner and outer horizon areas is independent of mass; a simple connection with left- and right-moving temperatures of a dual field theory is proposed here. This directly connects to the observation that inner horizons play crucial roles in computing reflection and transmission coefficients, despite the fact that the scattering problem is set up without regard to behavior at the inner horizon. Drawing on ongoing work, we will suggest a new interpretation for how to understand the role of inner horizons in scattering problems; as a byproduct, this may lead to a different way of computing greybody factors from the classic method of matched asymptotic expansions.

SHUNJI MATSUURA, McGill University
Protected boundary states in gapless topological phases

I will talk about gapless topological phases of (semi-)metals and nodal superconductors. Using both K-theory and dimensional reduction procedures, a classification of topologically stable Fermi surfaces in (semi-)metals and nodal lines in superconductors is derived. We discuss a generalized bulk-boundary correspondence that relates the topological features of the Fermi surfaces and superconducting nodal lines to the presence of protected zero-energy states at the boundary of the system.

STEFAN MENDEZ-DIEZ, University of Alberta
Elliptic curves, KR-theory and T-duality

There are several variants of string theory. We will explore how the different string theories compactified on an elliptic curve are related via T-duality by studying the classification of elliptic curves with involution through the topological lens of KR-theory.

MARCO MERKLI, Mathematics, Memorial University
Repeated Interaction Quantum Systems

Consider a quantum system interacting sequentially in time, one by one, with a chain of infinitely many independent, identical other quantum systems. One may think of a scattering experiment. The entire system is an open system, due to the infinite size of the chain. We give an overview of recent results on the dynamics of such repeated interaction quantum systems. Among them are the existence and the construction of an asymptotic state and its thermodynamic properties, the influence of possible randomness, and an analysis of multi-time quantum measurements performed on chain elements after interaction. The results are based on collaborations with L. Bruneau and A. Joye, and with M. Penney.

ROBERT MILSON, Dalhousie University
A Conjecture on Exceptional Orthogonal Polynomials

Exceptional orthogonal polynomials (so named because they span a non-standard polynomial flag) are defined as polynomial eigenfunctions of Sturm-Liouville problems. By allowing for the possibility that the resulting sequence of polynomial degrees admits a number of gaps, we extend the classical families of Hermite, Laguerre and Jacobi. In recent years the role of the Darboux (or the factorization) transformation has been recognized as essential in the theory of orthogonal polynomials spanning a non-standard flag. In this talk we present the conjecture that ALL such polynomial systems are derived as multi-step factorizations of classical operators and offer some supporting evidence.

ALEXI MORIN-DUCHESNE, Université de Montréal
Periodic loop models and extended XXZ Hamiltonians

Non hermitian Hamiltonians play an important role in the description of two dimensional statistical models such as the Fortuin-Kasteleyn model and the Q-Potts spin model. The loop Hamiltonians, as elements of the periodic Temperley-Lieb algebra $TLP_N(\beta)$, are examples of such Hamiltonians: their eigenvalues are real and they are not diagonalizable for specific values of the parameter β.

Loop Hamiltonians are known to be related to XXZ Hamiltonians and a great deal can be learned from this correspondence. In my talk, I will introduce the "twist" representations of the periodic Temperley-Lieb algebra and show how one can study the Jordan structure of the loop Hamiltonian in these representations, using tools from the XXZ models.

MANU PARANJAPE, Université de Montréal
Solitons and instantons in an effective model of CP violation

CP violation in the standard model is generated in the weak interactions and the CKM mass matrix. However, asymptotic states involved in such processes almost invariably involve hadronic mesonic asymptotic states, for example in recent experiments decays of B mesons to 2 K mesons and 2 π mesons are most important. Thus it should be possible to describe CP violation entirely in terms of scalar fields. We, however, study a 1+1 dimensional analog of a 3+1 dimensional model describing CP violating decays entirely in terms of effective scalar fields. Although the equations of motion are non-linear, we find exact soliton and instanton solutions. The solitons are of the Q-ball type and represent particle states in the quantum theory while the instantons have finite action and should mediate tunnelling transitions in the theory. We speculate as to the 3+1 dimensional analogs of the exact solutions that we have found.

SARAH POST, Centre de Recherches Mathematiques, Univ. de Montreal
Recent advances in the theory of superintegrable systems

In this talk, I will discuss new results in the theory of superintegrable systems: Hamiltonian systems with more integrals of motion than degrees of freedom. The talk will consist of a brief survey of known results along with a focus on recent advances. In particular on the relationship between such systems and orthogonal polynomials. Topics to be discussed: new infinite families of superintegrable systems and recurrence relations for orthogonal polynomials, representations of symmetry algebras and the Askey scheme, and superintegrable spin chains.

WALID ABOU SALEM, University of Saskatchewan
Adiabatic evolution of coupled surface and internal waves

I discuss the dynamics of interacting surface and internal water waves over a slowly varying random bottom. Signature of such waves has been observed in pictures from the space station. The motion of the interacting waves is described by a system of coupled Schroedinger-Korteweg-de Vries equations. In the presence of a slowly varying random bottom, the coupled waves evolve adiabatically over a long time scale. The analysis covers the cases when the surface wave is a stable bound state or a long-lived metastable state.