Abstracts of Invited Talks

Louis Pierre Arguin  City University of New York
“The maxima of the Riemann zeta function in a short interval of the critical line”
A conjecture of Fyodorov, Hiary & Keating states that the maxima of the modulus of the Riemann zeta function on a short interval of the critical line behave similarly to the maxima of a disordered system with logarithmic correlations. In this talk, we will discuss a proof of this conjecture to leading order, unconditionally on the Riemann Hypothesis. We will highlight the connections between the number theory problem and the relevant spin glasses (REM and disordered polymers on a tree), which exhibit a 1-RSB freezing transition.
This is joint work with D. Belius (Zurich), P. Bourgade (NYU), M. Radizwill (McGill), and K. Soundararajan (Stanford).

Roland Bauerschmidt  University of Cambridge
“Spin systems and interacting random walks”
I will briefly review the role of random walks in the study of spin systems. I will then present a new relation that shows directly that the Goldstone mode of hyperbolic sigma models (in any dimension) is described by an interacting random walk (the vertex reinforced jump process).

Gyan Bhanot  Rutgers University
“What are physicists doing working at the Cancer Institute?”

Marek Biskup  UCLA
Christian Borgs  Microsoft
“From Graph Limits to Non-Parametric Graph Models and Recommendation Systems”
Graphons were invented to model the limit of large, dense graphs. While this led to interesting applications in combinatorics, most applications require limits of sparse graphs. In this talk, I will review recent progress on graph limits for sparse graphs, and then discuss a couple of applications: non-parametric modelling of sparse graphs, and recommendation systems where the matrix of known ratings is so sparse that two typical users have never rated the same item, making standard similarity based recommendation algorithms challenging. This is joint work with Jennifer Chayes, Henry Cohn, and many others.

Jasna Brujic  NYU
“Self-assembly and Folding of Colloidal Emulsion Polymers”
An important goal of self-assembly is to achieve a preprogrammed structure, which can respond to external queues to perform a specific function.
Here we show that DNA-mediated droplet interactions can be finely tuned in a way that ensures the self-assembly of colloidal emulsion polymers with a broad distribution of chain lengths.
The obtained distributions are consistent with a random branching model for droplets with pre-prescribed valencies, indicating that the self-assembly process is well mixed and goes to completion.
We show that these polymers are freely-jointed chains and that their size R scales with the number of monomers N as R=bN^a, where b is the droplet diameter (or Kuhn length) and a=3/4, in agreement with the Flory theory for a dilute polymer in a good solvent in 2D. In addition, we find that the diffusion
constant of the center of mass of the polymer scales as $D \sim N^{1/2}$, suggesting that the hydrodynamic drag force on the polymer due to the solvent is important. Finally, we introduce and trigger secondary DNA interactions along the polymer backbone to fold it into several simple yet distinguishable structures. This physical system demonstrates the possibility of controlling the self-assembly of monomer droplets into polymers, which in turn allows us to study their collapse and folding to explore their physical bases from a new perspective.

The authors are: Angus McMullen, Alexander Grosberg, Jasna Brujic.

**Almut Burchard**

University of Toronto

The optimal transportation problem defines a notion of distance on the space of probability measures over a manifold, the *Wasserstein space*. In his 1994 Ph.D. thesis, McCann discovered that this space is a length space: the distance between probability measures is given by the length of minimizing geodesics called *displacement interpolants*. A surprising number of important functionals in physics and geometry turned out to be geodesically convex.

I will describe recent work with Benjamin Schachter on differentiating functionals (such as the entropy or the Dirichlet integral) along displacement interpolants. Starting from an Eulerian formulation for the underlying optimal transportation problem, we take advantage of the system of transport equations to compute derivatives of arbitrary order, for probability densities that need not be smooth.

**Henry Cohn**

Microsoft

**Pierluigi Contucci**

University of Bologna

"Species and Scales in the Gaussian Spin Glasses"

The seminar will present some generalisation of the Sherrington and Kirkpatrick model where the covariance function is endowed with a multi-scale or a multi-specie structure. Rigorous results will be illustrated and open problems discussed.

**Percy Deift**

New York University

"On the asymptotic behavior of a log gas in the bulk scaling limit in the presence of a varying external potential"

Abstract. We study the determinant $\det(I - \gamma K_s)$, $0 < \gamma < 1$, of the integrable Fredholm operator $K_s$ acting on the interval $(1, 1)$ with kernel $K_s(\lambda; \mu) = (\sin s(\lambda - \mu)) / (\lambda - \mu)$. This determinant arises in the analysis of a log-gas of interacting particles in the bulk-scaling limit, at inverse temperature $\beta = 2$, in the presence of an external potential $\nu = -1/2 \ln(1 - \gamma)$ supported on an interval of length $2s/\pi$. We evaluate, in particular, the double scaling limit of $\det(I - \gamma K_s)$ as $s \to \infty$ and $\gamma \to 1$, in the region $0 \leq \kappa = \nu/s = -1/2 \ln(1 - \gamma) \leq 1 - \delta$, for any fixed $0 < \delta < 1$. This problem was first considered by Dyson in 1995.

**Bertrand Duplantier**

IPhT Université Paris-Saclay

**Subhro Ghosh**

National University of Singapore

"Two manifestations of rigidity in random point sets: forbidden regions and maximal degeneracy"
A point process is said to be "rigid" if its local observables are completely determined (as deterministic functions of) the point configuration outside a local neighbourhood. For example, it has been shown in earlier work that, in the Ginibre ensemble (a.k.a. the 2D Coulomb gas at inverse temperature beta=2), the point configuration outside any bounded domain determines, almost surely, the number of points in the domain.

In this talk, we will explore two recent manifestations of such rigidity phenomena. For the zeros of the planar Gaussian analytic function, we show that outside every large "hole", there is a "forbidden region" which contains a vanishing density of points. This should be seen in contrast with the corresponding situation for classically understood models (e.g. random matrix ensembles), where no such effects are known to occur.

In the second part of the talk, we will consider "stealthy" hyperuniform systems, which are systems whose structure function (i.e., the Fourier transform of the two-point correlation) vanishes near the origin. We show that such systems exhibit "maximal degeneracy", namely the points outside a bounded domain determine, almost surely, the entire point configuration inside the domain. En route, we establish a conjecture of Zhang, Stillinger and Torquato that such systems have (deterministically) bounded holes. Based on joint works with Joel Lebowitz and Alon Nishry.

Gian Michele Graf
ETH Zurich
“Disorder and topology. The cases of Floquet and of chiral systems”
We will present a new formulation of bulk and edge indices for disordered Floquet systems. A byproduct is a space-time duality stating the equivalence of two settings: two systems may be placed next to one another in space or operate one after the other in time. A different type of systems to be addressed are disordered chiral chains, which may be viewed as Su-Schrieffer-Heeger models with random hopping. There localization occurs at all but possibly one energy, which is enough to endow the model with topological features. Different formulations of the index will be introduced and related to the Lyapunov spectrum of the chain.

Rafael Greenblatt
University of Roma Tre
“Singular behavior of the Lyapunov exponent of a product of random 2×2 matrices and a related continuous process”
We consider a certain infinite product of random 2×2 matrices appearing in the exact solution of some 1 and 1+1 dimensional disordered models in statistical mechanics, which depends on a deterministic real parameter ε and a random real parameter with distribution μ. For a large class of μ, we prove a prediction by B. Derrida and H. J. Hillhorst (1983) that the Lyapunov exponent behaves like C ε^2α in the limit ε→0, where α ∈ (0,1) is determined by μ. The proof is made possible by a contractivity argument which makes it possible to control the error involved in using an approximate stationary distribution similar to the original proposal, along with some refinements in the estimates obtained using that distribution.
A limiting procedure gives a continuum process whose leading Lyapunov estimate admits an exact formula, which also allows us to reformulate part of the argument by McCoy and Wu for the presence of an essential singularity in the free energy of the two-dimensional Ising model with columnar disorder. (Joint work with F. Comets, G. Giacomin and G. Genovese)

Alexander Grosberg
New York University
“From Sisyphus to Boltzmann: an example of repulsive depletion interaction”
While depletion interaction, e.g., between two plates in an equilibrium system (such as a colloidal solution) is an attraction, we show how colloids driven by a colored Ornstein-Uhlenbeck noise may leave to the counter-intuitive opposite effect. This is due to the accumulation of lackadaisical particles in the gap between plates. The underlying physical effect is the difference between white noise drive, which sets particle energy fluctuations of order $kT$ (Boltzmann limit), and colored noise drive with long persistence time, which controls particle propulsion ("pushing") force (Sisyphus limit).

David Huse
Princeton University

William Irvine
University of Chicago

Vojkan Jaksic
McGill University

“Statistical Mechanics of Repeated Quantum Measurements”

The statistics of the (finite alphabet) outcomes of repeated quantum measurements is studied by methods of thermodynamic formalism. Viewed as one-dimensional spin systems with long range interactions, repeated quantum measurements exhibit very rich (and sometimes very singular) thermodynamic behaviour. We will describe general thermodynamical formalism of these systems and illustrate its unexpected features on a number of examples.

This talk is based on joint works with T. Benoist, N. Cuneo, Y. Pautrat, and C-A. Pillet.

Antti Kupiainen
University of Helsinki

Dov Levine
Technion

Andrea Liu
University of Pennsylvania

“How glasses relax and go with the flow”

All solids flow at high enough applied stress and melt at high enough temperature. Crystalline solids flow and premelt via localized particle rearrangements that occur preferentially at structural defects known as dislocations. The population of dislocations therefore controls both how crystalline solids flow and how they melt. In disordered solids, there is considerable evidence that localized particle rearrangements induced by stress or temperature occur at localized flow defects but all attempts to identify them directly from the structure have failed. Here we introduce a novel application of machine learning data mining methods to diagnose flow defects, or “soft” particles from their local structural environments. We follow the softness of each particle as it evolves under deformation or temperature. Our results show that machine learning methods can be used to gain a conceptual understanding that has not been achieved with conventional approaches.

Bruno Nachtergaele
University of California, Davis

“Dimerization in a class of SU(n) invariant quantum spin chains.”

We use a random loop representation to prove dimerization in the ground states of a family of SU(n) invariant quantum spin chains. This class of models has been studied in the literature for several decades by a range of methods, which have revealed some rather special properties. Previous results strongly pointed to the occurrence of dimerization and this work provides a direct proof of dimerization for all sufficiently large values of the spin. I will also discuss results and open problems concerning dimerization in other spin chains. This is joint work with Daniel Ueltschi.
Chuck Newman  New York University

“Remarks on the Riemann Hypothesis”

One fairly standard version of the Riemann Hypothesis (RH) is that a specific probability density on the real line has a moment generating function (Laplace transform) that as an analytic function on the complex plane has all its zeros pure imaginary. We'll review a series of results that span the period from the 1920's to 2018 concerning a perturbed version of the RH. In that perturbed version, due to Polya, the log of the probability density is modified by a kind of mass term (in quantum field theory language). This gives rise to an implicitly defined real constant known as the de Bruijn-Newman Constant, Lambda. The conjecture and now theorem (Newman 1976, Rodgers and Tau 2018) that Lambda is greater than or equal to zero is complementary to the RH which is equivalent to Lambda less than or equal to zero. We'll briefly discuss some connections with quantum field theory and the Lee-Yang circle theorem.

Ron Peled  Tel Aviv University

Fyl Pincus  University of California, Santa Barbara

“Effective charge of hydrated ions”

We apply an earlier model1 for Hydrogen bonds in water to the case of hydrated ions.

In the cartoon above (downloaded from Google Images), the standard picture that the water dipoles are oriented, e.g. with the protons toward anions and vice-versa. This is engendered by the ionic electrostatic potential. However since each program has four possible proton sites (tetrahedral coordination), there are, on average (for bulk water), two protons per oxygen. However for hydration waters near an anion, there is a potential advantage for higher proton occupancy on a given oxygen ion at the cost of Coulomb repulsions with the pre-existing protons. The result is a build-up of positive charge within the hydration layer which renormalizes down the ionic charge.

Dave Pine  New York University

Jeff Schenker  Michigan State University

“Localization (and resonant delocalization?) of a disordered polaron”

Polaron models describe the motion of a tracer particle interacting with a quantum field. The Holstein Hamiltonian describes a tight binding particle interacting with a field of harmonic oscillators. We will consider the Holstein Hamiltonian with the addition of on-site disorder in the tracer particle potential. Provided the hopping amplitude for the particle is small, we are able to prove localization for matrix elements of the resolvent, in particle position and in the field Fock space. These bounds imply a form of dynamical localization for the particle position that leaves open the possibility of resonant tunneling in Fock space between equivalent field configurations. Some related deformations of the Anderson model in which we can prove the existence of resonant tunneling will be presented, but the exact nature of the dynamics for the disordered Holstein model remains open. (Joint work with Rajinder Mavi.)
Avy Soffer  
Rutgers University

Phil Sosoe  
Cornell University

“The chemical distance in 2D percolation”
The critical phase of two dimensional Bernoulli percolation is now well understood rigorously, in terms of detailed descriptions at the qualitative level, and even exact computations of critical exponents and scaling limits for some models. One quantity of physical interest which has remained mysterious is the chemical distance, the graph distance inside percolation clusters. I will report on recent this problem with Jack Hanson and Michael Damron.

Presad Tetali  
Georgia Tech

Sal Torquato  
Princeton University

David Vanderbilt  
Rutgers University

“Axion insulators”
Topological insulators such as Bi2Se3 exhibit a quantized orbital magnetoelectric coupling, known as an axion coupling, which is reflected in the presence of a half-integer quantum anomalous Hall response on any gapped surface. However, unless the time-reversal symmetry that protects the bulk topology is broken at the surface, the surface is necessarily metallic and the axion response is hidden. Here I will introduce a broader class of topological crystalline insulators such that the quantized axion coupling is protected by other symmetries, such as inversion, in such a way that the surfaces are naturally gapped. Unfortunately, materials realizations currently remain elusive. Nevertheless, I will present some results of our exploration of simple tight-binding models of such systems, and will describe some of the interesting properties such materials are expected to display, including chiral edge channels flowing along surface steps and facet intersections.

Simone Warzel  
Technical University of Munich

Peter Winkler  
Dartmouth

“Large Random Permutations”
Permutations admit natural limit structures, together with a variational principle that permits "seeing" what a large random permutation with given characteristics looks like. (Joint work with Rick Kenyon, Dan Kral’ and Charles Radin.)

Emil Yuzbashyan  
Rutgers University

Riccardo Zecchina  
Bocconi University & ICTP

Ofer Zeitouni  
Weizmann Institute of Science