

Abstracts of Invited Talks

Michael Aizenman Princeton University

Topological roots of the fermionic structures seen in the 2D Ising model

Pavel Bleher Indiana University-Purdue University Indianapolis

Six-vertex model with partial domain wall boundary conditions. Exact solution

We present an exact solution to the large N limit of the six-vertex model with partial domain wall boundary conditions in the ferroelectric phase. This is a joint work with Karl Liechty.

Leonid Bunimovich Georgia Institute of Technology

Transport processes from mechanics

I will discuss the simplest mechanical systems which allow rigorous derivation of transport processes.

Eric Carlen Rutgers University

Nonequilibrium steady states and approach to them for a simple kinetic model

We study several kinetic models of BGK type with one or more thermostats that act globally on the system. When there is only one thermostat entropy methods easily give uniqueness of the obvious Maxwellian steady state. In the presence of more than one thermostat the situation is more complex and interesting. For several models of this type we prove uniqueness of the steady state, and exponential approach to them. The results are non-perturbative. That is, we are not only concerned with small temperature differences and initial data close to Maxwellian. This is joint work with Raffaello Esposito, Joel Lebowitz, Rossana Marra and Clement Mouhot.

Dmitry Dolgopyat University of Maryland

Local Limit Theorem for Sums of Independent Random Variables

We prove Local Limit Theorem and obtain a two-term Edgeworth expansion for sums of independent random variables satisfying appropriate tightness conditions.

Weinan E

Princeton University

The Stability of Laminar Shear Flow

In 1883, Reynolds published his classical work on the experimental study of the stability of shear flow and transition to turbulence. Since then the issue of the critical Reynolds number at which laminar flows become unstable has been studied by numerous people, including Sommerfeld, Heisenberg, C. C. Lin, Orazag, and more recently, Trefethen, Hof, Barkley, Eckhardt, Waleffe et. al. Despite this great deal of effort, there is still a lack of the proper mathematical framework for understanding such nonlinear instabilities. In this talk, we present a theoretical framework using ideas drawn from statistical physics and large deviation theory. We then present the results of our intensive numerical study of the shear flow using this framework.

This is joint work with Jianchun Wang and Qianxiao Li.

Peter Fratzl

Max Planck Institute of Colloids and Interfaces

A simple model recapitulating aspects of tissue growth controlled by geometric boundary conditions

The shape of tissues arises from a subtle interplay between biochemical and physical driving forces, controlling cell proliferation and differentiation as well as extracellular matrix formation. Tissues growing under physical constraints imposed by the surrounding environment, often respond to mechanical signals due to these constraints. Despite the inherent complexity of such systems, much can still be learnt by treating tissues which permanently remodel as simple fluids. In this approach, tissue remodeling introduces fluidity on long time scales and relaxes all internal shear stresses leaving only the pressure arising from tissue growth, which is counterbalanced by the surface stress. This model is used to investigate how substrates influence the stability of tissue nodules in phenomena such as healing [1].

[1] Fischer FD, Zickler GA, Dunlop JWC, Fratzl P. 2015. J. R. Soc. Interface 12: 20150108.

Hillel Furstenberg

Hebrew University of Jerusalem

Rational orbits, diophantine approximation and the $3n+1$ problem

A number of number-theoretic questions can be reformulated as questions regarding "special" orbits in particular dynamical systems. These may be referred to as "rational orbits". One such question has to do with approximating algebraic numbers by rationals. Another is the famous question regarding the transformation on the integers $T(n) = (3n+1)$ divided by the highest power of 2 leaving the result an integer.

Giovanni Gallavotti Rutgers University

On the hierarchical model and the Kondo effect

A manifestation of the Kondo effect is the non divergence at zero temperature of the susceptibility of an impurity magnetization to the action of a field. It is a quantum phenomenon not accessible to perturbation theory because it is essential that the interaction with the host lattice electrons is antiferromagnetic, no matter how small. Its theory in one dimension, due to Wilson, is based on the renormalization group and its interest is that it has been one of the first and few cases in which a multiscale phenomenon controlled by a non trivial fixed point has been understood. Here I shall discuss a hierarchical model for a system exhibiting the Kondo effect: its nine running couplings (of which 2 are relevant 4 are marginal and 3 irrelevant) flow under a beta function which can be computed exactly and which generates a flow with several properties which give a picture of the phenomenon. (collaboration with G.Benfatto and I.Jauslin)

Michael Goldstein University of Toronto

Quasi-periodic operators and Korteweg-de Vries equations with quasi-periodic initial data. Report on recent progress

This talk will report on results on quasi-periodic operators developed in recent joint works and ongoing projects with I.Binder, D.Damanik, M.Lukic, W.Schlag and M.Voda.

Michael Jakobson University of Maryland

Ergodic properties of some attractors with countable Markov partitions

We study ergodic properties of SRB measures for certain piecewise smooth two-dimensional systems with countable Markov partitions. In our earlier works with Sheldon Newhouse (1996, 2000) we proved that respective dynamical systems are isomorphic to Bernoulli shifts. In this work under additional assumptions we prove exponential decay of correlations. We use the classical results of Ruelle and

Bowen, and the results from the work of Omri Sarig "Thermodynamic formalism for countable Markov shifts" (1999)

Vojkan Jaksic

McGill University

Adiabatic theorems and Landauer's principle in quantum statistical mechanics

The Landauer principle asserts that the energy cost of erasure of one bit of information by the action of a thermal reservoir in equilibrium at temperature T is never less than $k_B T \log 2$. We discuss Landauer's principle for quantum statistical models describing a finite level quantum system S coupled to an infinitely extended thermal reservoir R and link the saturation of Landauer's bound to adiabatic theorems in quantum statistical mechanics (for states and relative entropy). Furthermore, by extending the adiabatic theorem to Renyi's relative entropy, we extend the Landauer principle to the level the Full Counting Statistics (FCS) of energy transfer between S and R . This allows to elucidate the nature of Landauer's principle FCS fluctuations.

This talk is based on joint works with Tristan Benoist, Martin Fraas, and Claude-Alain Pillet.

Chris Jarzynski

University of Maryland

Shortcuts to adiabaticity in simple classical systems

Adiabatic invariants play an important role in classical mechanics, quantum mechanics and thermodynamics. Within the field of quantum control, "shortcuts to adiabaticity" are strategies for preserving the quantum adiabatic invariant under arbitrarily fast driving. An analogous classical problem in one degree of freedom can be stated as follows. Given a time dependent kinetic-plus-potential Hamiltonian $H(q,p,t)$, we wish to construct a potential $U(q,t)$ (which vanishes at $t=0$ and $t=\tau$) with the property that all trajectories launched from a specified initial energy shell E_0 of $H(q,p,0)$, and subsequently evolving under $H(q,p,t) + U(q,t)$, will end on a single energy shell E_τ of $H(q,p,\tau)$. In other words, time evolution under $H+U$ maps the initial energy shell E_0 to the final energy shell E_τ . By Liouville's theorem these two shells enclose the same volume of phase space. In this manner the potential $U(q,t)$ steers the trajectories so that the final value of the adiabatic invariant is identical to the initial value, for every trajectory and for arbitrarily fast time-dependence of $H(q,p,t)$. I will present a simple solution to this problem and will discuss its relationship to analogous solutions for quantum systems.

Lana Jitomirskaya University of California, Irvine

Very small denominators, sharp arithmetic spectral transitions and sharp description of non-uniformly hyperbolic dynamics

We will report on the recent constructive proof of sharp arithmetic spectral transition for the almost Mathieu operator. In the regime of positive Lyapunov exponents, spectral/dynamical properties differ for Diophantine and Liouville frequencies and/or phases. We will address the question of the location and nature of the corresponding transition, presenting sharp arithmetic results for both Diophantine frequencies/all phases and all frequencies/Diophantine phase cases. Close to the transition regime eigenfunctions decay at the non-Lyapunov rate, and we will also present a sharp description of the eigenfunction profile and also of the non-uniformly hyperbolic dynamics of the corresponding transfer-matrix cocycle. The talk is based on works joint with W. Liu.

Anatole Katok Pennsylvania State University

Flexibility of entropies and Lyapunov exponents for smooth dynamical systems

Entropies and Lyapunov characteristic exponents for “physical” (Sinai-Ruelle-Bowen) measures as well as topological entropy and exponents with respect to the maximal entropy (Bowen-Margulis) measure are essential numerical measures of exponential complexity of orbit behavior. With few exceptions they cannot be precisely calculated.

The flexibility program looks for finding general restrictions for those numbers and their interrelations that are expected to be few, and to showing that within those restrictions all values can be attained. I will discuss non-trivial progress that has been reached in two areas: geodesic flows on surfaces (joint with Alena Erchenko), and area-preserving diffeomorphisms on three-dimensional manifolds (joint with Jaime Bochi and Federico Rodriguez Hertz; in progress). I will outline general conjectures and mention some specific interesting problems.

Kostya Khanin University of Toronto

Renormalization and rigidity for a class of non-linear Interval exchange transformations

We shall discuss rigidity theory for non-linear interval exchange transformations corresponding to surfaces of genus 1. Such transformations can be considered as circle homeomorphisms with multiple break points. A non-trivial time-reversible symmetry for the renormalization transformation is the key property which allows to study the hyperbolicity of renormalizations and establish rigidity results.

Yuri Kifer

Hebrew University

A Glimpse at Nonconventional Limit Theorems

Nonconventional limit theorems deal with the asymptotic behavior of sums of the form $\sum_{n=1}^N F(\xi(q_1(n)), \xi(q_2(n)), \dots, \xi(q_\ell(n)))$ where F is a function, $\xi(n), n \geq 0$ is a stochastic process with some stationarity properties, in particular, it can be generated by a measure preserving transformation T in the form $\xi(n) = f \circ T^n$ where f is a function. The functions $q_j(n), j = 1, \dots, \ell$ take on nonnegative integer values on nonnegative integers and they satisfy some properties, for instance, they may have the form $q_j(n) = jn$. We discuss first the crucial question on positivity of the limiting variance for the sums above, then concentrate on the case when $\xi(1), \xi(2) \dots$ are i.i.d. where explicit formulas are available and, if time permits, exhibit new results concerning the nonconventional local limit theorem, Berry-Esseen type estimates and the functional central limit theorem for the case when $q_j(n)$'s are general integer valued polynomials.

Alex Kontorovich

Rutgers University

Applications of Ruelle transfer operators

We will discuss some simple problems in number theory, geometry, and dynamics, which can be attacked using "congruence" versions of Ruelle transfer operators, among other tools. No prior knowledge of these topics is assumed.

Roman Kotecky

University of Warwick

Metastability for continuum interacting particle systems

Gabriel Kotliar

Rutgers University

Hunds Metals: a New Road to Strongly Correlated Electron Behavior

Over the past thirty years, substantial effort has been devoted to describing materials near a Mott transition. In these systems, correlation effects (i.e. departures from free electron behavior) derive from strong on site repulsion (Hubbard U terms). Recently attention has turned to a different origin of strong correlation phenomena which is rooted in the Hund's coupling J term.[1] Notable examples of these materials are the new iron based high temperature superconductors and the ruthenium oxides. Hunds metals are well described by Dynamical Mean Field Theory, and are characterized by the phenomena of orbital spin separation [2,3]. We will present an elementary introduction to the theory of Hunds metals and to the experimental signatures which distinguish them from materials near a Mott transition

[1] K. Haule and G. Kotliar, New J. Phys. 11, 025021 (2009).

[2] Aron and G. Kotliar, Phys. Rev. B 91, 041110 (2015).

[3] K. Stadler et. al. Phys. Rev. Lett. 115, 136401 (2015)

Jorge Kurchan École Normale Supérieure

The dynamics of evolving populations as thermal systems

A remarkable mapping was noted in the past few years that relates the dynamics of a population of M individuals undergoing random mutations and selection, and that of a single system in contact with a thermal bath with temperature $1/M$. This correspondence holds under the restrictive condition that the population is dominated by a single type at almost all times, punctuated by rare, successive mutations. I will argue that such thermal dynamics holds much more generally, specifically in systems with rugged fitness landscapes. This includes cases where a number of concurrent mutants dominate the population. Non-trivial suggestions from statistical mechanics may be thus proposed for evolutionary systems -- including a large part of the numerical simulation procedures -- that in many cases would have been anti-intuitive without this background.

Elliott Lieb Princeton University

A Pfaffian formula for monomer-dimer partition functions

The monomer-dimer covering problem shows up in several areas of physics and other fields. While the partition function of the pure dimer covering problem on planar lattices was solved ages ago by Kasteleyn and Fisher-Temperley in terms of

Paffians (whose squares are easily computable determinants), the inclusion of monomers (i.e., vertices uncovered by dimers) is an intractable problem. Together with Alessandro Giuliani and Ian Jauslin we have succeeded in utilizing an ancient theorem* to write the partition function of a restricted monomer-dimer problem as a Pfaffian. This is the model in which monomers are allowed on the boundary vertices of an arbitrary planar graph.

*J. Combinatorial Theory 5, 313-319 (1968).

Carlangelo Liverani

Deterministic Friedlin—Wentzell phenomena

I will illustrate a simple example of deterministic system of the fast-slow type that exhibit a behaviour qualitatively similar to a small random perturbation of a ODE. In particular, metastability phenomena are possible. Yet, I will explain that there may be important quantitative differences.

I will conclude with few remarks on the relevance of such an example for non-equilibrium statistical mechanics.

Valerio Lucarini

University of Hamburg University of Reading

Response and Fluctuations in Geophysical Fluid Dynamics

The climate is a complex, chaotic, non-equilibrium system featuring a limited horizon of predictability, variability on a vast range of temporal and spatial scales, instabilities resulting into energy transformations, and mixing and dissipative processes resulting into entropy production. Despite great progresses, we still do not have a complete theory of climate dynamics able to encompass instabilities, equilibration processes, and response to changing parameters of the system. We will outline some possible applications of the response theory developed by Ruelle for non-equilibrium statistical mechanical systems, showing how it allows for setting on firm ground and on a coherent framework concepts like climate sensitivity, climate response, and climate tipping points. We will show results for comprehensive global climate models. The results are promising in terms of suggesting new ways for approaching the problem of climate change prediction and for using more efficiently the enormous amounts of data produced by modeling groups around the world.

V. Lucarini, R. Blender, C. Herbert, F. Ragone, S. Pascale, J. Wouters,
Mathematical and Physical Ideas for Climate Science, Reviews of Geophysics 52,
809-859 (2014)

Clement Mouhot University of Cambridge

Commuting the mean-field and classical limits in quantum mechanics

We report on a joint work with F. Golse and T. Paul, where we establish quantitative mean-field limit estimates for the many-body Schrödinger equation for bosons with binary interaction potential, that are uniform along the classical limit. This relies on revisiting an argument of Dobrushin for deriving the Vlasov in the classical mean-field limit and introducing a quantum analogous of the Monge-Kantorovich distance.

Yakov (Yasha) Pesin Pennsylvania State University

Sinai-Ruelle-Bowen measures for surface diffeomorphisms

For the two dimensional case I will discuss an affirmative solution of a long-standing conjecture by Viana that a surface diffeomorphism f of positive topological entropy that is non-uniformly hyperbolic on a set of positive volume possesses an SRB measure. The proof is based on representing f as a Young's diffeomorphism. In particular, f admits a symbolic representation by a collection of towers for which: 1) the base is a carefully constructed rectangle which consists of intersections of stable and unstable curves; 2) the inducing time is the first return time to the base. Moreover, every hyperbolic ergodic measure for f can be lifted to one of these towers. This is a joint work with V. Climenhaga and S. Luzzatto.

Luc Rey-Bellet University of Massachusetts

Thermodynamic formalism and the numerical analysis of stochastic systems

We analyze operator splitting schemes for Markov processes, with the parallelization of kinetic Monte-Carlo as a guiding example. We study these schemes in particular in the long-time (steady-state) regime by using information theoretic tools (relative entropy rate) to compare the original process with the approximate process generated by the numerical scheme. Combined with information inequalities related to the thermodynamic formalism, this allows to control weak errors in the long-time regime. In addition our approach provide a-posteriori estimates that can be tracked in straightforward manner in numerical simulations.

Eugene Speer

Rutgers University

Translation invariant extensions of finite volume measures

Given a probability measure on the set of particle configurations on a finite subset of a lattice, can it be extended to a translation invariant measure on configurations on the entire lattice? When the answer is yes, what are the properties, e.g., the entropy, of such an extension? We give reasonably complete answers for the one-dimensional case; in higher dimensions we can say much less. This is joint work with S. Goldstein, J. L. Lebowitz, and T. Kuna.

Tom Spencer

Institute for Advanced Study

A strong central limit theorem in 2D statistical mechanics

Domokos Szasz

Budapest university of technology

Fourier law from Hamiltonian dynamics

The rigorous derivation of Fourier's law of heat conduction for an interacting system of Hamiltonian particles is a classical and fundamental goal of statistical physics. The ballpiston system will be introduced, being a dimension-reduced-version of a 2008 model of Gaspard and Gilbert. The direct aim is to treat its rare interaction limit leading to the mesoscopic master equation, i. e. a Markov jump process for the energies of the particles. In absence of straightforward mathematical tools, our approach relies on Chernov-Dolgopyat averaging applied to a subsystem. Joint works with P. B'alint, Th. Gilbert, P. N'andori, IP. T'oth.

David Vanderbilt

Rutgers University

How to visualize topological insulators

In physics, we invent visualization tools such as vectors, phase diagrams, and field lines to assist in our intuitive understanding of complex phenomena. In recent years there has been an explosion of interest in topological insulators and related states. In these materials, the Bloch functions defined on the 3-torus Brillouin zone are twisted in a way that cannot be unraveled without a gap closure, and topological indices are defined to characterize the type of twist. With this motivation, I will present what I think is a useful visualization tool for

characterizing the different states in topological insulators. The basic idea is to choose one lattice direction in which to Wannierize, and plot the 1D Wannier centers (or equivalently, the Wilson loop eigenvalues) as a function of the other two wave vector coordinates. I will demonstrate that this approach is closely related to the inspection of surface states, but without going beyond bulk calculations.

Raghu Varadhan New York University

Michael Vogelius Rutgers University

Victor Yakhot Boston University

Small-scale universality in turbulence

It is well - known that to accurately measure magnitudes of exponents of the moments of inertial -range velocity increments, one has to experiment on extremely high-Reynolds -number flows. That is why no data on the moments of the order $n > 8$ are not available. Studying moments of *velocity derivatives*, we have discovered that even in the low-Re flows at $R_\lambda \geq 10$, one observes well-resolved anomalous scaling exponents, related to those in the inertial range. Numerical values of these exponents, found in isotropic turbulence, convection cell and wall flows, are the same. It is also shown that in all studied flows the transition to anomalous behavior occurs at $R_\lambda \approx 10$.

Lai-sang Young New York University

The many faces of SRB measures

SRB measures are well known to be *the* natural physical measures for chaotic dissipative dynamical systems that are autonomous. Many real-world systems, on the other hand, have stochastic components; they may be driven, time-dependent, leaky, and so on. In this talk, I will argue that ideas surrounding SRB measures can be adapted to these more realistic settings. To illustrate the point, I will offer a few rigorous results and some applications.