Alexandre Hannud Abdo
Manipulation of Several Particles under Chaotic Diffusion

Institute of Physics, University of Sao Paulo, Brazil

In this work, we argue that we can manipulate and alter the dynamics of several particles by using small controlling perturbations on the basic diffusive dynamical system. Such control does modify the invariant natural measure associated with a trajectory on the chaotic set according to some pre-established objective.

Daniel Alonso and Antonia Ruiz
Transport in polygonal billiard chains

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In this work we study the transport properties of point particles in a polygonal billiard chain. The dynamics in these billiards has different properties depending on the parameters of the system. In all cases the Liapunov exponents and the Kolmogorov-Sinai entropy are zero, in this sense there is no microscopic chaos. We find, from numerical simulations, that for certain parameters there is diffusion as well as heat transport. On the other hand for other set of parameters transport is anomalous.

V.E.Arkhincheev
Fractal diffusion equations: microscopic models with anomalous diffusion and its generalizations

Buryat Science Center, Ulan-Ude, Russian Federation

To describe the "anomalous" diffusion the generalized diffusion equations of fractal order are deduced from microscopic models such as the comb model and Levy flights. It is shown that three types of equations are possible: with fractional temporal, fractional spatial derivatives and mixed derivatives. The solutions of these equations are obtained and the physical sense of these fractional derivatives is discussed. The relation between diffusion and conductivity is studied also and the well known Einstein relation is generalized for the anomalous diffusion case.
Péter Bálint

Correlation decay in the planar periodic Lorentz gas with ’soft’ obstacles

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Budapest, Hungary

I would like to report on some work in progress, joint with Imre Péter Tóth. Consider the following natural modification of the periodic planar Lorentz gas: the obstacles are no longer hard balls, the moving particle may enter them. More precisely, the hard core potentials are replaced by other circularly symmetric potentials of finite range. V. Donnay and C. Liverani obtained ergodicity for a large class of such models in the 90’s. Our aim is to extend their results by proving exponential decay of correlations under specific conditions.

Nikolai Chernov

Dynamics of a massive piston in an ideal gas

Department of Mathematics, University of Alabama at Birmingham, USA

We study a dynamical system consisting of a massive piston in a cubical container of large size $L$ filled with an ideal gas. The piston has mass $M \sim L^2$ and undergoes elastic collisions with $N \sim L^3$ non-interacting gas particles of mass $m = 1$. Under suitable initial conditions, there is, in the limit $L \to \infty$, a scaling regime with time and space scaled by $L$, in which the motion of the piston and the one particle distribution of the gas satisfy autonomous coupled equations (hydrodynamical equations). We prove that the mechanical trajectory of the piston converges, in probability, to the solution of the hydrodynamical equations for a certain period of time. On the other hand, we have observed experimentally that during longer periods of time the mechanical trajectory of the piston can, under certain conditions, diverge far from the corresponding solutions of the hydrodynamical equations with probability close to 1. In that case the piston experiences large oscillations that damp very slowly. This phenomenon is traced to the instability of the hydrodynamical equations.
E. G. D. Cohen

Phase transitions in a class of systems with nonintegrable attractive interactions

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In systems with attractive interactions $1/r^\alpha$ with $0 < \alpha < 3$, (which includes the Newtonian gravitational potential $-1/r$) two types of transitions can occur, when studied in the microcanonical ensemble. A gravitational transition, leading to a collapse of the system in a core-halo configuration or a normal first order transition. This behavior depends crucially on the magnitude of the cutoff used to regularize the potential near $r = 0$. The corresponding phase diagrams as well as the method to obtain them will be outlined.

Predrag Cvitanović

Spatiotemporal chaos in terms of unstable recurrent patterns

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If everything in a turbulent systems is in constant flux, how is it that humans are able to distinguish different kinds of turbulence? Hopf’s answer was that dynamics drives a given spatially extended system through a repertoire of unstable patterns; as we watch a given “turbulent” system evolve, every so often we catch a glimpse of a familiar pattern. For any finite spatial resolution, the system follows approximately for a finite time a pattern belonging to a finite alphabet of admissible patterns, and the long term dynamics can be thought of as a walk through the space of such patterns, just as chaotic dynamics with a low dimensional attractor can be thought of as a succession of nearly periodic (but unstable) motions.

I will describe a modest implementation of Hopf’s program on a 1-dimensional spatially extended Kuramoto-Sivashinsky system, a PDE that describes interfacial instabilities such as unstable flame fronts.
S. Denisov, J. Klafter, M. Urbakh

Manipulation of Dynamical Systems by Symmetry Breaking

School of Chemistry, Tel-Aviv University, Tel-Aviv 69978, Israel

We propose an approach to manipulate and control transport in Hamiltonian systems which are characterized by a mixed phase space. The approach is based on symmetry breaking of the phase space structure by applying a zero-mean periodic force for a finite duration of time. This induces time and space reversal asymmetry, which modifies the internal dynamics of the system and leads to directed transport. It is shown that our strategy allows to perform manipulations both with individual particles and with statistical ensembles of particles.

Carl Dettmann

Fractal asymptotics

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Recent advances in the periodic orbit theory of stochastically perturbed systems have permitted a calculation of the escape rate of a noisy chaotic map to order fifty in the noise strength. Comparison with the usual asymptotic expansions obtained from integrals, and with a previous calculation of the electrostatic potential of exactly selfsimilar fractal charge distributions, leads to a remarkably precise form for the late terms in the expansion, with parameters determined independently from the fractal repeller and the critical point of the map. Borel resummation gives a precise meaning to the asymptotic expansion, which can then be compared to the escape rate as computed by alternative methods.
The question of how reversible microscopic equations of motion can lead to irreversible macroscopic behavior has been one of the central issues in statistical mechanics for more than a century. The basic issues were known to Gibbs. Boltzmann conducted a very public debate with Loschmidt and others without a satisfactory resolution. In recent decades there has been no real change in the situation. In 1993 we discovered a relation, subsequently known as the Fluctuation Theorem (FT), which gives an analytical expression for the probability of observing Second Law violating dynamical fluctuations in thermostatted dissipative nonequilibrium systems. The relation was derived heuristically and applied to the special case of dissipative nonequilibrium systems subject to constant energy "thermostatting". These restrictions meant that the full importance of the Theorem was not immediately apparent. Within a few years, derivations of the Theorem were improved but it has only been in the last couple of years that the generality of the Theorem has been appreciated.

The Fluctuation Theorem does much more than merely prove that in large systems observed for long periods of time, the Second Law is overwhelmingly likely to be valid. The Fluctuation Theorem quantifies the probability of observing Second Law violations in small systems observed for a short time. In other words, the Fluctuation Theorem generalizes the Second Law to finite systems observed for finite times. Unlike the Boltzmann equation, the FT is completely consistent with Loschmidt’s observation that for time reversible dynamics, every dynamical phase space trajectory and its conjugate time reversed ‘anti-trajectory’, are both solutions of the underlying equations of motion. Indeed the standard proofs of the FT explicitly consider conjugate pairs of phase space trajectories. Quantitative predictions made by the Fluctuation Theorem regarding the probability of Second Law violations have been confirmed experimentally, both using molecular dynamics computer simulation and very recently in laboratory experiments involving optical tweezers.
Christina Forster, H.A. Posch

Lyapunov instability of two-dimensional fluids

University of Vienna

The phase-space trajectory of many-body systems is Lyapunov unstable. Recently we have found that for hard-particle systems the perturbations associated with specific Lyapunov exponents exhibit coherent spatial structures to which we refer as Lyapunov modes. They are reminiscent of the hydrodynamic modes of continuum mechanics. The mode belonging to the maximum Lyapunov exponent is strongly localized in space, and only a small fraction of the particles contributes to the norm of the associated tangent vector at any instant of time. This ratio vanishes in the thermodynamic limit. In contrast, the perturbations generating the smallest positive Lyapunov exponents are fully delocalized and have a wave-like coherent appearance reminiscent of the classical odes of fluctuating hydrodynamics.

Here, we consider systems with a one-parametric family of interaction potentials (parameter $p$), interpolating between a two-dimensional Weeks-Chandler-Anderson (WCA) fluid ($p = 0$) and a hard-disk system ($p = 1$). The localization of the perturbation for the maximum exponents is gradually weakened for $p < 1$, but it still persists for the WCA case even in the thermodynamic limit. The coherent structures associated with the small exponents (in the absolute sense), however, are still present for very steep potentials, $p > 0.9$, but cannot unambiguously be demonstrated for softer interaction potentials. The reason for this surprising result are the unexpected large fluctuations of the time-dependent local Lyapunov exponents.

Katrin G. Gelfert

All volume expanding dynamical systems have positive topological entropy

Max Planck Institute for the Physics of Complex Systems

One major significance of the topological entropy is its strong relation to other dynamical invariants such as Lyapunov exponents, topological pressure, fractal dimension, and Hausdorff dimension, which provides our primary motivation. Almost all previous investigations of the topological entropy have been concerned with upper bounds. Exact formulas have been derived under strong smoothness assumptions only. In this talk we will give lower bounds of the topological entropy of $C^1$-smooth dynamical systems on Riemannian manifolds which are sharp in some cases. They are formulated in terms of the phase space dimension and of the exponential growth rates of a singular value function of the tangent map. These rates correspond to the deformation of $k$-volumes and can for instance be estimated in terms of Lyapunov exponents. Examples address Henon maps, the Lorenz system, the geodesic flow on a (not necessarily compact) Riemannian manifold without conjugate points, and skew product systems.
D.H.E. Gross

Geometric foundation of thermo-statistics including non-extensive systems: phase transitions and Second Law

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Microcanonical thermodynamics
see: cond-mat/0201235
cond-mat/0206341
You may also look at: http://publish.aps.org/ and click on the right buttom and you see the front cover of the most recent PRL with our figure.

Jörg Lehmann, Peter Reimann, Peter Hänggi

Throwing ropes over oscillating barriers

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Escape problems in the presence of explicit time-dependent driving is at the root of many timely transport processes. Typical examples comprise the control of reactions with tailored laser pulses, ion transport through voltage-gated channels, the pumping and shuttling of particles in Brownian environments, to name only a few. Here, we address thermally activated escape of a Brownian particle over a periodically oscillating saddle point in N dimensions. In doing so, one has to evaluate classes of optimal paths connecting stable with unstable time-periodic manifolds, see Fig. 1. Extending our previously developed time-dependent path-integral formalism for the one-dimensional driven escape problem [1, 2], we are able to derive asymptotically exact weak-noise expressions for the instantaneous and the time-averaged escape rate . In particular, we generalize our approach for the systematic treatment of the rate prefactor and the action. In the special case of a one dimensional metastable, piecewise parabolic potential it is possible to evaluate our expressions in closed analytical form, both for the overdamped and the inertial dynamics. Comparing our predictions with results from a numerical solution of the corresponding Fokker-Planck equation (in the overdamped case) and from simulations of the stochastic dynamics (for the case with inertia), we find excellent agreement for a wide range of parameters; see for instance Fig. 2 for the mass-dependence of the time-averaged escape rate. (the figures are on the conference webpage)

Takahisa Harayama

Parameter dependent diffusion coefficients of chaotic billiards

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The parameter dependent diffusion coefficients of strongly chaotic dynamical systems are investigated for billiards in an external field and flower shape billiards. We analyze their functional form by different schemes. The methods we use are based either on heuristic higher-order corrections to the simple random walk model, on lattice gas simulation methods, or they start from a suitable Green-Kubo formula for diffusion. We show that dynamical correlations, or memory effects, are of crucial importance to reproduce the precise parameter dependence of the diffusion coefficient.

Pisut Tempatarachoke and Dennis Isbister

The Fermi-Pasta-Ulam Oscillating Chain: thermostatting mechanisms

School of Physics, University of New South Wales, ADFA, Canberra, AUSTRALIA

The thermal conduction of heat energy along a one dimensional chain of interacting nonlinear oscillators is still very much an anomaly since the pioneering work of Fermi, Pasta and Ulam in 1952. The seemingly straight forward response of this system to a temperature gradient does not lead to a finite thermal conductivity coefficient as expected. It appears that the heat current is ‘too small’ (in a number of particles, N, sense) to ensure that the thermal conductivity exists in the thermodynamic limit. We have examined the effects of the thermostatting mechanisms responsible for the temperature gradient and update these findings here at this meeting.
Wolfram Just

Equilibrium Phase Transitions in Coupled Map Lattices: A Pedestrian Approach

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A class of piecewise linear coupled map lattices with simple symbolic dynamics is constructed. It can be solved analytically in terms of the statistical mechanics of spin lattices. The corresponding Hamiltonian is written down explicitly in terms of the parameters of the map. The approach follows the line of recent mathematical investigations. But the presentation is kept elementary so that phase transitions in the dynamical model can be studied in detail. Although the method works only for map lattices with repelling invariant sets some of the conclusions, i.e. the role of local curvature of the single site map and properties of the nearest neighbour coupling might play an important role for phase transitions in general dynamical systems.

Nickolay Korabel

Fractal structures of normal and anomalous diffusion in nonlinear nonhyperbolic dynamical systems

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A paradigmatic nonhyperbolic dynamical system exhibiting deterministic diffusion is the smooth nonlinear climbing sine map. We show that this map generates fractal hierarchies of normal and anomalous diffusive regions as functions of the control parameter. The measure of these self-similar sets is positive and parameter-dependent with a fractal diffusion coefficient in case of normal diffusion. By using a Green-Kubo formula we link these fractal structures to the nonlinear microscopic dynamics in terms of fractal Takagi-like functions.
O. V. Kuklina\textsuperscript{1}, A. V. Tur\textsuperscript{2}, A. V. Yanovsky\textsuperscript{3}, V. V. Yanovsky\textsuperscript{4}

**DYNAMIC FRAGMENTATION AND DETERMINISTIC CHAOS**

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\textsuperscript{2}Center D’etude Spatiale Des Rayonnements, C.N.R.S.-U.P.S., 9, ave. Colonel-Roche 31028 TOULOUSE CEDEX 4.

\textsuperscript{3}Institute for Low-Temperatures Physics and Engineering, National Acad. Sci. Ukraine, Lenin ave. 47, 61164 Kharkov, Ukraine.

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A one-dimensional fragmentation model is proposed. In this model the discrete maps are taken to be the evolution laws of the fragmentation process. For the tent and logistic maps the asymptotics of the fragment size distribution function in the small-scale fragment range follow an exponential law in the chaotic regime of fragmentation (Lyapunov exponent $\lambda_L > 0$) and a power law in the regular regime ($\lambda_L \leq 0$). The results of numerical simulation of the process confirm theoretically predicted asymptotics. Dependences of an exponential function increment on a map parameter and, thus, on $\lambda_L$ were obtained from numerical data analysis for the tent map. Complex dependence of this increment on the map parameter correlated with the map bifurcation structure in logistic map case was analyzed.

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Baowen Li

**Heat conductivity in linear mixing systems**

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We study heat conduction in a two dimensional billiard model which consists of two parallel lines of length $L$ at distance $d$ and a series of triangular scatterers with internal angles either irrational or rational multiple of $\pi$. In both cases, no particle can move between the two reservoirs without colliding with the triangles. Our model has linear instability, thus zero Lyapunov exponents. It is found that if all the internal angles of the triangular scatterers are irrational multiples of $\pi$, the model exhibits nice diffusive properties and the numerical value of the thermal conductivity computed via a Green-Kubo approach agrees with the one obtained by direct numerical simulations with thermal baths. The heat conduction obeys the Fourier law. However, if all internal angles of the triangular scatterers are rational multiple of $\pi$, the model has an abnormal diffusion and a divergent thermal conductivity. Our results demonstrate that the Fourier heat law does not need exponential instability.
This work investigates a semi-dispersive three dimensional billiard system through computer simulation. A cell is constructed with convex cylindrical walls and the motion of a point particle moving inside this cell is considered. I discuss briefly dispersive and semi-dispersive systems. I explain how Lyapunov exponents may be measured from the simulated system. The measured Lyapunov exponents and velocity correlation functions are discussed. In particular, I discuss some anomalies in the results of the velocity correlation function measurements.


Appropriate Hőlder exponents for an active tracer field

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[2] Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Silver Street, Cambridge CB3 9EW, United Kingdom

Concentrations of chemically or biologically active tracers in flows may have a complex spatial structure. It has been shown that such a structure can be characterized by a Hölder exponent[1]. We show here that for a complete characterization a set of Hölder exponents is needed. We compare our results with data from various models.

Reference:
Manabu Machida, Keiji Saito, and Seiji Miyashita

Frequency Dependence of Quantum Localization in a Periodically Driven System

Department of Applied Physics, School of Engineering, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656

We studied the quantum localization phenomena for a periodically driven GOE random matrix Hamiltonian, which is regarded as the Hamiltonian for a complexly interacting system under a periodic external field. As the external field oscillates, the ground state energy diffuses, and then suddenly the energy gets saturated to various values depending on the frequency. We numerically obtained the saturated energy as a function of the frequency. On the other hand, we counted the number of the Floquet eigenvectors which have large overlap with the initial ground state. We also found this overlap is localized and this relevant number of Floquet eigenvectors takes various values depending of the frequency. We obtained this number as a function of the frequency. That is, the system localizes both in energy space and in the Floquet space. Finally, we focus on the case that the frequency is sufficiently small. Then, the transitions of states take place only at avoided crossing. Transitions between the two neighboring levels are typically described by the Landau-Zener formula. In this situation, we consider the analogy to the Anderson localization in the quantum localization of the present model and assume the localization length of energy space is proportional to that of the Floquet space. We found the Landau-Zener picture still works although a naive picture of successive independent Landau-Zener transitions fails because quantum interference is essential to the quantum localization.
There is a relation between the irreversibility of thermodynamic processes as expressed by the breaking of time-reversal symmetry, and the entropy production in such processes. We explain on an elementary mathematical level the relations between entropy production, phase-space contraction and time-reversal starting from a deterministic dynamics. Both closed and open systems, in the transient and in the steady regime, are considered. The main result identifies under general conditions the statistical mechanical entropy production as the source term of time-reversal breaking in the path space measure for the evolution of reduced variables. This provides a general algorithm for computing the entropy production and to understand in a unified way a number of useful (in)equalities. Important are a number of old theoretical ideas for connecting the microscopic dynamics with thermodynamic behavior and for the discussion on macroscopic fluctuations. We also discuss the Markov approximation. We give various examples including the case of heat conduction networks. In that case, we study networks of interacting oscillators, driven at the boundary by heat baths at possibly different temperatures. A set of first elementary questions are discussed concerning the uniqueness of a stationary possibly Gibbsian density and the nature of the entropy production and the local heat currents. We also derive a Carnot efficiency relation for the work that can be extracted from the heat engine. Most of the course is based on three papers:


Hydrodynamic behavior for Lyapunov exponents

The computation of Lyapunov exponents in large systems of hard disks has revealed a structure made of a discrete spectrum plus a continuous part. The phase-space directions corresponding to the discrete part of the Lyapunov spectrum are collective deviations of particles, resembling hydrodynamic excitations. We have developed a theory based on a Boltzmann equation, generalized so as to include a dependance on deviation vectors, which permit to account for those small-frequency long wave-length directions. We also present evidence that similar behavior is present in dense and solid systems.
We study the appearance of directed energy current in homogeneous spatially extended systems coupled to a heat bath in the presence of an external ac field $E(t)$. The systems are described by nonlinear field equations. By making use of a symmetry analysis we predict the right choice of $E(t)$ and obtain directed energy transport for systems with a nonzero topological charge $Q$. We demonstrate that the symmetry properties of motion of topological solitons (kinks and antikinks) are equivalent to the ones for the energy current. Numerical simulations confirm the predictions of the symmetry analysis and, moreover, show that the directed energy current drastically increases as the dissipation parameter $\alpha$ reduces. Our results generalize recent rigorous theories of currents generated by broken time-space symmetries to the case of interacting many-particle systems.
Since the foundation of Ludwig Boltzmann’s famous kinetic equation in 1872 there has been a tremendous development to understand nonequilibrium processes in classical and quantum systems. A kinetic equation which unifies the achievements of transport in dense gases with the quantum transport of dense Fermi systems is presented [1,2,7]. The quasiparticle drift of Landau’s equation is connected with a dissipation governed by a nonlocal and non-instant scattering integral in the spirit of Enskog corrections. These corrections are expressed in terms of shifts in space and time that characterise non-locality of the scattering process [3]. In this way quantum transport is possible to recast into a quasiclassical picture. Compared to the Boltzmann-equation, the presented form of virial corrections only slightly increases the numerical demands in implementations [4]. Applications range from impurity systems in solid state physics [1] to heavy ion collisions in nuclear physics [3,6] where recent experimental puzzles could be solved. Anomalous expansion velocities appear due to the included correlations which can be interpreted in terms of Tsallis statistics and which is a signal of phase transition [8]. Consequences of this time delayed kinetic equation are an interplay between continuous differential equation and discrete mapping and chaotic time dependence of the distribution function can occur [9]. The balance equations for the density, momentum and energy include quasiparticle contributions and the second order quantum virial corrections beyond the Landau theory. In this sense a non Fermi-liquid behaviour is appearing. The medium effects on binary collisions are shown to mediate the latent heat, i.e., an energy conversion between correlation and thermal energy [5,7].


130 years Boltzmann equation - from classical to nonlocal quantum transport

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G.E. Norman

Molecular Relaxation and Chaos in Many-Particle Systems

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Divergence of Molecular Trajectories. Lyapunov instability is inherent to the many-particle dynamic molecular systems. Diverse manifestations of it obtained by molecular dynamics method are given.

Dynamical Memory Time. The concept of dynamical memory time $t_m$ is discussed. The value of $t_m$ determines the time interval during which the behavior of molecular-dynamical system can be predicted from initial conditions and deterministic equations of motion at a certain level of accuracy defined by a particular scheme of numerical integration and time step $\Delta t$ value. The relation between $t_m$, fluctuation of total energy $\Delta E$ and $K$-entropy (Lyapunov exponent) is treated.

Chaotic and Dynamic Properties of Molecular Systems. It is concluded that molecular dynamics method is a method which retains Newtonian dynamics only at the times less than $t_m$ and carries out a statistical averaging over initial conditions along the trajectory run.

Homogeneous Nucleation in Metastable States. The simulation peculiarities are treated, which are related to the Lyapunov instability of the molecular systems. The concept of dynamical memory time $t_m$ is exploited. An approach is developed for the estimation of the activation energy and rate for the homogeneous nucleation in superheated solids and liquids. Results for homogeneous nucleation in superheated crystal are discussed.

Boltzmann and Non-Boltzmann Relaxation. Two stages of the relaxation of nonequilibrium two component strongly coupled plasmas were observed. The initial stage is characterized by an oscillatory behavior of kinetic energy of electrons accompanied by a fast relaxation of the velocity distribution function. In the further relatively slow Boltzmann stage the kinetic energies of charges exponentially approach the equilibrium. The character of the relaxation process is compared with the extension of electrons to vacuum from the surface of an initially homogeneous plasma slab.

Conclusion. Meaning of $t_m$ for real systems is related to the thermal and Langevin noise and quantum uncertainty. Possible influence of $t_m$ variation on some characteristics is discussed.

A. Pikovsky

ANOMALOUS CORRELATIONS IN HAMILTONIAN LATTICES

Department of Physics, University of Potsdam

We investigate scaling properties of Lyapunov vectors in space-time chaos. It is demonstrated that in models with fast decay of correlations in space and time the statistics of the Lyapunov vector belongs to the Kardar-Parisi-Zhang universality class for roughening interfaces. Contrary to this, in Hamiltonian lattices the statistics of Lyapunov vectors definitely deviates from the KPZ one. We explain this by anomalous correlations of some observables.
LAMBERTO RONDONI

ON A DEFINITION OF NEAR EQUILIBRIUM ENTROPY

Politecnico di Torino

A dynamical definition of the entropy of near equilibrium steady states is proposed and discussed in the framework of thermostatted particle systems. The proposal is based on the analysis of the phase space distributions of thermostatted (dissipative) systems, adapting to such systems the Green’s expansion of the equilibrium entropy. Nevertheless, the proposal appears to be applicable to other systems as well.

Frank Schmüser

An Ising spin chain with two alternating temperatures

Max-Planck-Institut für Physik komplexer Systeme

Results on a kinetic Ising model are presented that evolves according to a generalization of Glauber rates, such that spins at even (odd) lattice sites experience a temperature $T_e$ ($T_o$). Detailed balance is violated so that the spin chain settles into a non-equilibrium stationary state. We will address the following three questions:

1. In the framework of a perturbation theory where the temperature difference between the two sub-lattices is the small parameter, we compute the first two orders of the correction to the Boltzmann distribution.
2. For arbitrary two temperatures, we could obtain all spin correlations in the stationary non-equilibrium state.
3. The entropy production in this model will be discussed and will be related to recent general approaches to entropy production.
Fluctuations of the energy injection rate in a turbulent shear flow

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The purpose of the investigation is to check whether the predictions of the fluctuation theorem that are valid for time-reversible chaotic and thermostatted non-equilibrium systems do also hold for more general cases. Our flow is a shear flow, driven by a volume force $f_x(y)$ that sustains a sinusoidal laminar flow profile $U_x(y)$. Stress-free boundary conditions are applied in the shear direction $y$. To this end, we investigate the fluctuations of the energy injection rate, $\epsilon_{in} = u_x(x) f_x(y)$, following the spirit of the experiments of Ciliberto and Laroche (J. Phys. IV 8, 215 (1998)) and Goldberg et al. (Phys. Rev. Lett. 87, 245502 (2001)). We find that the local $\epsilon_{in}(x)$ obeys a relation $\pi(\epsilon_{in}) = \exp(\text{const} \epsilon_{in}) \pi(-\epsilon_{in})$ globally for the full volume and also when resolved with respect to shear direction $y$. The PDF’s are not Gaussian.
The Lyapunov exponent is widely used as the quantity to express the dynamical instability and the amount of the information of dynamical systems. In general there is a Lyapunov exponent for each degree of freedom in the dynamical valuables, and the sorted set of such Lyapunov exponents, known as the Lyapunov spectrum, has been the subject of study in many-particle systems. Some algorithms for numerical computations of Lyapunov spectra are well known (eg. the algorithm due to Benettin et al. and constraint methods), and a recent rapid development of computers has made it possible to calculate Lyapunov spectra for larger systems. However an analytical calculation of full Lyapunov spectra for many-particle systems is still a difficult task at present, although some analytical methods for a part of the Lyapunov spectrum, such as the largest Lyapunov exponent, etc., have been proposed and applied to many-particle systems (eg. the kinetic approach and the geometric approach).

The master equation approach is one of the methods that can be used to calculate the full Lyapunov spectra for many-particle systems. This method is applied to systems with random particle interactions, and uses a master equation to describe the tangent space dynamics. Under the assumption that the random interactions are expressed by a Gaussian white randomness, the master equation is simply attributed to a Fokker-Planck equation, and leads to a direct connection between the Lyapunov exponents and the time correlation of the matrix specifying the particle interactions. We apply this method to the following two topics.

- **Stepwise structure of Lyapunov spectra**
  
  We consider one- and two-dimensional models using the master equation approach, in which a stepwise structure of the Lyapunov spectra appears in the region of small positive Lyapunov exponents. Long range interactions lead to a clear separation of the Lyapunov spectra into a part exhibiting the stepwise structure and a part changing smoothly. In these models a wave-like structure is found in the eigenstates of the particle interaction matrix.

- **Conjugate pairing rule for non-equilibrium thermostatted systems with a shear field**
  
  We consider iso-kinetic thermostatted systems with a shear flow sustained by an external boundary condition. An ”anti-Fokker-Planck equation” to describe the time-reversed tangent vector dynamics is introduced and used to calculate the negative Lyapunov exponents under the assumption of Gaussian white particle interactions. We show that the conjugate pairing rule is satisfied for thermostatted systems with a shear field in the thermodynamic limit.

Jan Wiersig

Devil’s Staircase in the Magnetoresistance of a Periodic Array of Scatterers

MPIPKS

The classical dynamics of electrons in a uniform magnetic field, a periodic potential, and an effective friction force is discussed. In the regime of nonlinear response to an external electric field, we find that the dynamical phenomenon of mode-locking becomes important, causing Devil’s staircases in the magnetoresistance and a complex phase diagram.

Daniel Wójcik

Transport in quantum multibakers

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We show that the transport in regular quantum multibaker map is ballistic in long time limit for any fixed value of Planck constant, however, for fixed time semiclassical limit leads to diffusion. The argument generalizes immediately to a large class of quantum lattice gases and we can argue that a sufficient condition for diffusion in the semiclassical limit is chaotic dynamics in each cell. This implies in particular that no interaction with external world (“decoherence”) is necessary for the diffusive behavior of a classical system.

Emmanuel ZABEY

Bizarre Heat Conduction in Harmonic Networks

University of Geneva, Switzerland

We consider a network of harmonic oscillators driven by stochastic heat reservoirs. The system goes towards a unique steady state if every degree of freedom “feels” the reservoirs. We state a condition on the coupling matrix that ensures this. Once the steady state is known to exist and to be unique, we can study its properties. In particular, we find that the heat transport may be very strange: although the Second Law of Thermodynamics is globally satisfied, some currents inside the network happen to flow from cold to hot.

This work was a diploma thesis under the supervision of Pr Jean-Pierre Eckmann.
In this paper we consider the diffusion in a homogeneous and isotropic medium of a macroscopic cloud of microscopic passive particles (i.e., those that do not affect the medium) characterized by a certain internal random-walk law. The latter circumstance relates this process to the class of stochastic transport, which is very popular in modern physics. Depending on the features of a random-walk at the microscopic level, the macroscopic transport equations for the cloud density may strongly differ from classical diffusion equations (while including the latter as a particular case) and involve, as a rule, fractional derivative with respect to space and/or time variables.

A specific problem to the solution of which this paper is devoted is the determination of the effect of the finiteness of a fixed velocity of particles \( v \) on the spreading of a cloud, i.e., taking into account the deviation from the standard model. When mean square of displacement of particles is infinite (so called Levy flights) but mean free path is finite the finiteness of \( v \) leads to renormalization of coefficients while leaving unchanged the fractional exponents of the effective equation. When mean free path is also infinite (enhanced superdiffusion - the case whether left unstudied or studied mistakenly) the situation is entirely different.

The solution of the problem on the determination of the asymptotic properties of the stochastic transport of microscopic particles has allowed us to derive new macroscopic equations describing the kinetics of this process with allowance for the finiteness of the velocity of particles. Despite a different type of the fractional derivatives involved, these equations proved to be very convenient for a sufficiently detailed analysis of the phenomena associated with the finiteness of \( v \): the transformation of the self-similarity of the Green’s functions, irreversible transformation of resting particles (whose number asymptotically tends to zero) into flying ones, and the importance of taking into account the dimension of the problem. All these questions can find direct practical application, in particular, to the study of radiative transfer in plasma.

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