

EUROPEAN ADVANCED STUDIES
CONFERENCE 4

“Chaos and Complex Systems”

Monastery of Novacella
Southern Tyrol, Italy
29 May 2003 - 1 June 2003

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EAS 4

**LIST OF SPEAKERS
AND PARTICIPANTS**

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Professor Dr. Vadim Anishchenko, Saratov, Russia

Mr. Thomas Behrens, Munich, Germany

Dr. Nils Berglund, Marseille, France

Professor Dr. Tassos Bountis, Patras, Greece

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Professor Dr. Aneta Stefanovska, Lancaster, United Kingdom

Dr. Gregor Veble, Como, Italy

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RECEPTION BY

Dr. Chrysostomus Giner, Head of the Monastery of Novacella

THURSDAY 29 May 2003

Augustini Hall

Head of the Monastery and Directors of the Conference

Reception for all Participants at Augustini Hall

Welcome Remarks

21:00-21:30

SUNDAY 1 June 2003

Augustini Hall

Closing Ceremony at Augustini Hall

09:00-09:30

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CONFERENCE SCHEDULE

FRIDAY 30 May 2003

Augustini Hall

P. Cvitanović (<i>Atlanta</i>) <i>Hopf's Last Hope</i>	09:00-10:00
V. Anishchenko (<i>Saratov</i>) <i>Statistical Properties of Chaotic Attractors</i>	10:00-11:00
COFFEE BREAK in Hartmann Hall	11:00-11:30
T. Bountis (<i>Patras</i>) <i>Discrete Breathers in Nonlinear Lattices ...</i>	11:30-12:00
T. Prosen (<i>Ljubljana</i>) <i>Fidelity of Quantum Chaos</i>	12:00-12:30
LUNCH	12:30-14:00
J.-P. Eckmann (<i>Geneva</i>) <i>Decay of Correlations and Liapunov Exponents</i>	14:00-15:00
E. Mosekilde (<i>Kgs. Lyngby</i>) <i>Border-Collision Bifurcations in a Managerial System</i>	15:00-15:30
M. Rosenblum (<i>Potsdam</i>) <i>Controlling Synchronization by Delayed Feedback</i>	15:30-16:00
COFFEE BREAK in Hartmann Hall	16:00-16:30
M. Robnik (<i>Maribor</i>) <i>Randomness of Classical Chaotic Motion</i>	16:30-17:00
P. McClintock (<i>Lancaster</i>) <i>Breakdown of Superfluidity in Liquid ^4He ...</i>	17:00-17:30
A. Stefanovska (<i>Lancaster</i>) <i>Inferring Parameters of Coupled Oscillators</i>	17:30-18:00
S. Hayes (<i>Munich</i>) <i>The Dynamics of a Hénon Family</i>	18:00-18:30
DINNER	18:30-20:00
S. Elaydi (<i>San Antonio</i>) <i>Global Stability of Periodic and Almost Periodic Orbits of Difference Equations</i>	20:00-21:00

SATURDAY 31 May 2003

Augustini Hall

G. Casati (*Como*)

Controlling the Energy Flow: Dynamical Instability, Diffusion ... **09:00-10:00**

P. Gaspard (*Brussels*)

The Origin of Stochasticity in Many-Particle Systems ... **10:00-11:00**

COFFEE BREAK in Hartmann Hall

11:00-11:30

V. Romanovskij (*Maribor*)

Time-Reversible Systems of Differential Equations **11:30-12:00**

N. Berglund (*Marseille*)

On the Noise-Induced Passage Through an Unstable Periodic Orbit **12:00-12:30**

LUNCH

12:30-14:00

M. Matsushita (*Tokyo*)

Pattern Formation in Bacterial Colonies ... **14:00-15:00**

L. Salasnich (*Milano*)

Formation and Dynamics of Soliton Trains ... **15:00-15:30**

G. Veble (*Como*)

Fidelity of the Perturbed Classical Evolution **15:30-16:00**

COFFEE BREAK in Hartmann Hall

16:00-16:30

J. M. G. Gómez (*Madrid*)

Quantum Chaos and $\frac{1}{f}$ Noise in Spectral Fluctuations **16:30-17:00**

H. Schomerus (*Dresden*)

Particle-Wave Duality in Mesoscopic Chaotic Transport **17:00-17:30**

H. Markum (*Vienna*)

Full Spectrum of Lyapunov Exponents in $U(1)$ Gauge Field Theory **17:30-18:00**

R. Meyer-Spasche (*Munich*)

Variable-Coefficient Difference Schemes ... **18:00-18:30**

DINNER

18:30-20:00

P. Šeba (*Praha*)

Random Matrix Theory and Arrival Statistics ... **20:00-20:30**

A. Ruffing (*Munich*)

Difference Schrödinger Operators ... **20:30-21:00**

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ABSTRACTS AND ADDRESSES

Statistical Properties of Chaotic Attractors

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Spectral and correlation characteristics are analyzed for chaotic attractors of spiral and "switching" types. Regularities of autocorrelation function decay and the spectral line width in the vicinity of the natural oscillation frequency are studied. The analysis is based on the analogue between the mentioned above types of attractors and classical models of stochastic processes, such as harmonic noise and a telegraph signal. The results of theory, numerical simulation and full-scale experiments are compared in detail. It is shown that all these data demonstrate a quite good agreement with each other. The main results discussed in the present lecture are described in the references below.

References

- [1] V.S. Anishchenko, T.E. Vadivasova, G.A. Okrokvetskikhov, G.I. Strelkova, Correlation Analysis of Dynamical Chaos, *accepted for publication in Journal Physica A, in press.*
- [2] V.S. Anishchenko, T.E. Vadivasova, A.S. Kopeikin, G.I. Strelkova, J. Kurths, Spectral and Correlation Analysis of Spiral Chaos, *Fluctuation and Noise Letters* **3** (2003), 2.

On the Noise-Induced Passage Through an Unstable Periodic Orbit

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We consider the stochastic exit problem from a planar domain whose boundary is an unstable periodic orbit, and which contains a stable periodic orbit. This problem arises when investigating the distribution of noise-induced phase slips between synchronized oscillators, or the phenomenon of stochastic resonance far from the adiabatic limit. We introduce a simple, piecewise linear model equation, for which the distribution of first-passage times can be precisely computed. In particular, we obtain a quantitative measure of the phenomenon of cycling: The first-passage density is proportional to a term depending periodically on the logarithm of the noise intensity, with a period related to the Lyapunov exponent of the orbit.

References

- [1] Martin V. Day, Conditional exits for small noise diffusions with characteristic boundary, *Ann. Probab.* 20 (1992) 1385-1419.
- [2] Robert S. Maier and D. L. Stein, Oscillatory behavior of the rate of escape through an unstable limit cycle, *Phys. Rev. Lett.* 77 (1996) 4860-4863.
- [3] Arkady Pikovsky, Michael Rosenblum, and Jürgen Kurths, Synchronization, a universal concept in nonlinear sciences, *Cambridge University Press* (Cambridge, 2001).
- [4] Nils Berglund and Barbara Gentz, A sample-paths approach to noise-induced synchronization: Stochastic resonance in a double-well potential, *Ann. Appl. Probab.* 12 (2002) 1419-1470.
- [5] Nils Berglund and Barbara Gentz, Geometric singular perturbation theory for stochastic differential equations, *J. Differential Equations* 191 (2003) 1-54.
- [6] Nils Berglund and Barbara Gentz, On the noise-induced passage through an unstable periodic orbit, in preparation.

Discrete Breathers in Nonlinear Lattices: A Review and Recent Results

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Localization phenomena in systems of many (often infinite) degrees of freedom have attracted attention in solid state physics, nonlinear optics, superconductivity and quantum mechanics. The type of localization we are concerned with here is *dynamic* and refers to oscillations occurring not because of the presence of some defect, but due to the interaction between nonlinearity and resonances. In particular, we shall describe an entity called *discrete breathers*, which represent localized periodic oscillations in nonlinear lattices. Here, we have chosen first to review the history of discrete breathers in the second half of last century and then present an account of our recent results on the efficient computation of breathers in multi-dimensional lattices using homoclinic orbits. This allows us to make a much more detailed study and classification of discrete breathers than had previously been possible, as well as accurately follow their existence and stability properties as certain physical parameters of the problem are varied.

References and Literature for Further Reading

- [1] R.S. MacKay and S. Aubry, *Nonlinearity* **7** (1994) 1623.
- [2] T. Bountis, H.W. Capel, M. Kollmann, J. Ross, J.M. Bergamin and J.P. van der Weele, *Phys. Lett. A* **268** (2000) 50.
- [3] S.Flach, *Phys. Rev. E* **51** (1995) 3579.
- [4] J.M. Bergamin, T. Bountis and M.N. Vrahatis, *Nonlinearity* **15** (2002) 1603.
- [5] J.M. Bergamin, T. Bountis and C. Jung, *J. Phys. A: Math. Gen.* **33** (2000) 8059.
- [6] J.M. Bergamin, Numerical approximation of breathers in lattices with nearest-neighbor interactions, to appear in *Phys. Rev. E* (2003).
- [7] T. Bountis, J.M. Bergamin and V. Basios, *Phys. Lett. A* **295**, (2002) 115.

**Controlling the Energy Flow:
Dynamical Instability,
Diffusion and Fourier Heat Law ***

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Given a particular classical, many-body Hamiltonian system, no transport theory can predict whether or not this specific Hamiltonian system yields an energy transport governed by the Fourier heat law. By using simple specific examples we analyse the relation between dynamical properties, correlations decay, diffusive behaviour and heat conduction. We show that, acting on the parameter which controls the strength of the on site potential inside a segment of the chain, we induce a transition from conducting to insulating behavior in the whole system. The control of heat conduction by nonlinearity opens the possibility to propose new devices such as a thermal rectifier. The connection with the survival probability and the so-called Loschmidt echo is briefly discussed.

(*) It seems there is no problem in modern physics for which there are on record as many false starts, and as many theories which overlook some essential feature, as in the problem of the thermal conductivity of nonconducting crystals.

Hopf's Last Hope: Spatiotemporal Chaos in Terms of Unstable Recurrent Patterns

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If everything in a turbulent system 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 new variational method for finding periodic orbits of flows and spatio-temporally periodic solutions of classical field theories, a generalization of the Newton method to a flow in the space of loops. The feasibility of the method is demonstrated by its application to several dynamical systems, including the Kuramoto-Sivashinsky system.

References and Literature for Further Reading

- [1] P. Cvitanović et al., Classical and Quantum Chaos, *Niels Bohr Institute, Copenhagen*, (2003), www.nbi.dk/ChaosBook
- [2] P. Cvitanović, Chaotic field theory, www.cns.gatech.edu/~predrag/papers/preprPOT.html.

Decay of Correlations and Liapunov Exponents

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This is a talk on work with P. Collet. In it we study and illustrate the question of how the decay of correlations in hyperbolic systems is related to the Liapunov exponents.

Global Stability of Periodic and Almost Periodic Orbits of Difference Equations

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Elaydi and Yakubu showed that a globally asymptotically periodic orbit in an autonomous difference equation must in fact be a fixed point whenever the phase space is connected. In this talk we extend this result to periodic and almost periodic nonautonomous difference equations via the concept of skew-product dynamical systems. We show that for a k -periodic difference equation, if a periodic orbit of period r is globally asymptotically stable, then r must be a divisor of k . In the case of almost periodic nonautonomous difference equations we appeal to a theorem of Sacker and Sell on “lifting” of dynamic properties in the setting of skew-product dynamical systems and show that a globally attracting uniformly asymptotically stable orbit gives rise to a compact invariant set K which is homeomorphic to the closure of the set of translates of the given system in an appropriate function space. In the case of an Almost Periodic system this implies the existence of an Almost Periodic solution.

References and Literature for Further Reading

- [1] S. Elaydi, *Discrete Chaos*, Chapman & Hall/CRC, Boca Raton, 2000
- [2] S. Elaydi, *An Introduction to Difference Equations, Second Edition*, Springer-Verlag, New York, 1999
- [3] S. Elaydi and A. Yakubu, Global stability of cycles: Lotka-Volterra competition model with stocking, *J. Diff. Equations and Appl.* **8(6)** (2002), 537-549.
- [4] A. Halanay and V. Rasvan, *Stability and stable oscillations in discrete time systems*, Taylor and Francis, 2000.
- [5] R. Sacker, Dedication to George R. Sell, *J. Diff. Equations and Appl.*, (preprint)
- [6] R. Sacker and G. Sell, Lifting properties in skew-product flows with applications to differential equations, *Memoirs Amer. Math. Soc.* **11(190)** (1977)

The Origin of Stochasticity in Many-Particle Systems of Statistical Mechanics

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Hamiltonian systems composed of many interacting particles typically present an exponential type of sensitivity to initial conditions characterized by positive Lyapunov exponents. On long-time scales, this sensitivity to initial conditions results into dynamical randomness characterized by a positive Kolmogorov-Sinai (KS) entropy per unit time. Dynamical chaos can thus explain the curious fact that the KS entropy per unit time is positive in a majority of systems of nonequilibrium statistical mechanics. The positive Lyapunov exponents are here reported in two types of systems: hard-ball models for the motion of a tracer or Brownian particle interacting with the particles of a surrounding fluid and microplasmas which are composed of positively charged ions confined in a Penning electromagnetic trap.

References and Literature for Further Reading

- [1] P. Gaspard, *Chaos, Scattering, and Statistical Mechanics* (Cambridge University Press, Cambridge UK, 1998).
- [2] P. Gaspard and H. van Beijeren, When do tracer particles dominate the Lyapunov spectrum? *J. Stat. Phys.* **109** (2002) 671.
- [3] P. Gaspard, Nonlinear dynamics and chaos in many-particle Hamiltonian systems, *accepted for publication in Progress in Theoretical Physics Supplement, in press.*
- [4] P. Gaspard, Sensitivity to initial conditions in microplasmas, *preprint.*

Quantum Chaos and 1/f Noise in Spectral Fluctuations

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A new approach to quantum chaos based on traditional methods of time series analysis has recently been proposed [1]. The essential feature of chaotic energy spectra in quantum systems is the existence of level repulsion and correlations. To study these correlations, we can consider the energy spectrum as a discrete signal, and the sequence of energy levels as a time series. In particular, spectral fluctuations can be characterized by the function $\delta_n = \sum_{i=1}^n s_i - n$, where s_i are the nearest level spacings of the unfolded energy spectrum. This function can be considered as a time series, where the level order index n plays the role of a discrete time.

The power spectrum $\langle S(k) \rangle$ of δ_n has been studied for representative energy spectra of regular and chaotic quantum systems. Neat power laws $\langle S(k) \rangle \sim 1/k^\alpha$ have been found in all cases. For Poisson spectra, we get $\alpha = 2$, as expected for independent random variables. For spectra of atomic nuclei at higher energies, in regions of high level density, and for the GOE, GUE and GSE ensembles, we obtain $\alpha = 1$. These results suggest the conjecture that *chaotic quantum systems are characterized by 1/f noise in the energy spectrum fluctuations*. This property is not a mere statistic to measure the chaoticity of the system. It provides an intrinsic characterization of quantum chaotic systems without any reference to the properties of Random Matrix Theory ensembles.

Work in progress [2] indicates that in a system like the Robnik billiard, where the order to chaos transition can be studied, an accurate power law behavior is obtained for $\langle S(k) \rangle$ throughout the transition.

References

- [1] J. M. G. Gómez, E. Faleiro, R. A. Molina, A. Relaño and J. Retamosa, Quantum chaos and 1/f noise, *Phys. Rev. Lett.* **89**, 244102 (2002).
- [2] J. M. G. Gómez, E. Faleiro, R. A. Molina, A. Relaño, J. Retamosa, M. Robnik, L. Salasnich and M. Vranicar: forthcoming preprint, to be published.

The Dynamics of a Hénon Family

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For the Hénon family $f(x, y) = (y, y^2 + ax)$, $0 < a < 1$, it will be shown that the two fixed points are the only real periodic points and that the basin of attraction of the origin has the stable manifold of the saddle fixed point as its boundary. Considered in \mathbf{R}^2 these maps are Morse-Smale diffeomorphisms, and considered in \mathbf{C}^2 the basin is a Fatou-Bieberbach domain.

Wigner Function Statistics of Quantum Maps

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We studied statistical properties of Wigner functions $W(x)$ of 1D quantum maps on compact phase space of finite area V . For this purpose we defined a Wigner function probability distribution $P(w) = 1/V \int \delta(w - W(x))dx$, which has, by definition, fixed first and second moment. In particular, we concentrate on relaxation of time evolving quantum state in terms of $W(x)$, starting from a coherent state.

We have shown that for a classically chaotic quantum counterpart the distribution $P(w)$ becomes a Gaussian distribution that is determined by the first two moments. The numerical studies were done on the quantum sawtooth map and the quantized kicked top. In a quantum system with Hilbert space dimension $N(\sim 1/\hbar)$ the transition of $P(w)$ to a Gaussian distribution was observed at times $t \propto \log N$.

In addition, it has been shown, that the statistics of Wigner functions of propagator eigenstates is a Gaussian as well in classically fully chaotic regime. We have also studied the structure of the nodal cells of the Wigner function, in particular the distribution of intersection points between the zero manifold and arbitrary straight lines.

References and Literature for Further Reading

- [1] M. Horvat, T. Prosen, Wigner function statistics in classically chaotic systems *J. Phys. A: Math. Gen* 36 (2003) 4015-4034

Full Spectrum of Lyapunov Exponents in U(1) Gauge Field Theory

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Results are presented for the full spectrum of Lyapunov exponents of the compact U(1) gauge system in classical field theory. Instead of the determination of the largest Lyapunov exponent by the rescaling method we now use the monodromy matrix approach. The Lyapunov spectrum L_i is expressed in terms of the eigenvalues Λ_i of the monodromy matrix M . In the confinement phase the eigenvalues lie on either the real or on the imaginary axes. This is a nice illustration of a strange attractor of a chaotic system. Positive Lyapunov exponents eject the trajectories from oscillating orbits provided by the imaginary eigenvalues. Negative Lyapunov exponents attract the trajectories keeping them confined in the basin. Latest studies concern the time-(in)dependence of the monodromy matrix. Further, we show that monopoles are created and annihilated in pairs as a function of real time in access to a fixed average monopole number.

References

- [1] T.S. Biró, H. Markum, R. Pullirsch, W. Sakuler, Observables of lattice gauge theory in Minkowski space, *hep-lat/0210020*.

Pattern Formation in Bacterial Colonies

- Experiments and Modelling

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We present experimental results of colony formation of bacteria and argue modeling attempts for them. Bacterial species *Bacillus subtilis* is known to exhibit at least five distinguishable types of colony patterns, depending on the substrate softness and nutrient concentration. We have established the morphological diagram of colony patterns, and then examined and characterized both macroscopically and microscopically how they grow. For instance, a concentric-ring-like colony grows cyclically with the interface repeating an advance (migration) and a stop (consolidation) alternately. Our experimental results suggest that macroscopically the most important factor for its repetitive growth is the cell population density, i.e., that there seem to be higher threshold of the cell population density to start migrating (initiation of migration phase) and lower one to stop migrating (initiation of consolidation phase). There have been quite a few phenomenological models to explain or reproduce observed patterns of bacterial colonies. A few of them are reviewed systematically and critically, based on our experimental results.

References and Literature for Further Reading

- [1] M. Matsushita, Formation of colony patterns by a bacterial cell population, in *Bacteria as Multicellular Organisms* eds. J A Shapiro and M Dworkin (Oxford UP, New York, 1997) 366-393.
- [2] J. Wakita, H. Shimada, H. Itoh, T. Matsuyama and M. Matsushita, Periodic colony formation by bacterial species *Bacillus subtilis*, *em J. Phys. Soc. Jpn.*, 70 (2001) 911-919.
- [3] M. Mimura, H. Sakaguchi and M. Matsushita, Reaction-diffusion modeling of bacterial colony patterns, *Physica A* 282 (2000) 283-303.

Breakdown of Superfluidity in Liquid ^4He : Nonlinear Response of an Electrostatically Driven Vibrating Grid

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The flow properties of pure He II in the limit of zero temperature have been probed using an electrostatically-driven vibrating grid. For small oscillation amplitudes (weak driving force), damping is negligible: the frequency response is a Lorentzian of extremely narrow width. As the driving amplitude is increased, the centre frequency at first decreases, with no evident rise in damping; then, above a critical amplitude, there is an onset of hysteretic nonlinear behaviour. Above a second critical amplitude, the damping rises dramatically and dissipative, viscous-like, behaviour is observed. The phenomena are discussed in terms of the growth of quantized vortex loops pinned to the grid, leading to the production of quantum turbulence.

References and Literature for Further Reading

- [1] C.F. Barenghi, R.J. Donnelly, W.F. Vinen, ed., *Quantized Vortex Dynamics and Superfluid Turbulence*, Springer, Berlin, 2001.
- [2] P.C. Hendry *et al.*, Macroscopic quantum tunnelling by vortices in isotopically pure He II *Phil. Trans. Roy. Soc. (Lond.) A* **332** (1990) 387–414.
- [3] L. Skrbek, J.J. Niemela, R.J. Donnelly, Four regimes of decaying grid turbulence in a finite channel, *Phys. Rev. Lett.* **85** (2000) 2973–2976.

Quantum and Classical Scattering Echoes: A Measure for the Topology of the Chaotic Saddle

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We study the quantum and classical scattering of Hamiltonian systems whose chaotic saddle is described by binary or ternary horseshoes. We are interested in parameters of the system for which a stable island, associated with the inner fundamental periodic orbit of the system exists and is large, but chaos around this island is well developed. In this situation, in classical systems, decay from the interaction region is algebraic, while in quantum systems it is exponential due to tunneling. In both cases, the most surprising effect is the appearance of echoes in the decay, *i. e.* an increment in the outgoing flux at some preferred times. The period of the scattering echoes coincides with the mean period, by which the scattering trajectories rotate around the stable orbit. We prove that this period of rotation is directly related to the development stage of the underlying horseshoe. We therefore propose the measurement of the period of the scattering echoes as an alternative method by which it is possible to obtain information on the topology of the hyperbolic component of the horseshoe which in turns, characterizes the global dynamics. Numerical test of these results in kicked one-dimensional scattering models and in scattering billiards and experimental realization in superconducting microwave billiards are presented.

References

- [1] C. Jung, C. Mejia-Monasterio, T.H. Seligman, Quantum and classical echoes in scattering systems described by simple Smale horseshoes, *Europhys. Lett.* 55 (2001) 616.

Variable-Coefficient Difference Schemes for Quasilinear Evolution Problems

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We review several integration methods leading to variable-coefficient schemes and/or to exact schemes for ordinary differential systems (functional fitting; Principle of Coherence). Conditions for obtaining coefficients that are independent of the time t and of the time step τ are investigated. Some of the discussed schemes lead to efficient difference schemes for problems from applications, in particular for highly oscillatory ordinary differential systems and for parabolic equations with blow-up solutions.

References and Literature for Further Reading

- [1] G. Denk, A new numerical method for the integration of highly oscillatory second-order ordinary differential equations, *Appl. Num. Math.* 13 (1993) 57-67.
- [2] M.J. Gander, R. Meyer-Spasche, An Introduction to Numerical Integrators Preserving Physical Properties, chap.5 in R.E. Mickens (ed.), Applications of Nonstandard Finite Difference Schemes, *World Scientific, Singapore*, 2000.
- [3] M.N. Le Roux, Semidiscretization in time of nonlinear parabolic equations with blowup of the solution, *SIAM J. Numer. Anal.* 31 (1994), 170-195.
- [4] R. Meyer-Spasche, Variable-Coefficient Difference Schemes for Quasilinear Evolution Problems, in: Numerical Methods and Applications, I. Dimov et al (eds), *Lecture Notes in Computer Science* 2542 (2003) 36-47.
- [5] K. Ozawa, Functional fitting Runge-Kutta method with variable coefficients, *Jap J Ind Appl Math*, 18 (2001), 107-130.

Border-Collision Bifurcations in a Managerial System

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Many problems in physics and engineering lead to piecewise-smooth dynamical systems. Examples are impact oscillators and problems associated with friction and finite clearances in mechanical engineering. Similar problems are encountered in economic and managerial systems. Human decision-making behavior, for instance, often entails logical considerations such that one type of decisions are made under certain circumstances while other conditions lead to a different type of decisions. The purpose of the present contribution is to discuss the bifurcation scenarios and transitions to chaos that one can observe in a production - distribution system with logical functions in the algorithm for order placements. We discuss how the border-collision bifurcations lead to transitions that are qualitatively different from the transitions we know for smooth dynamical systems. Period-doubling bifurcations, for instance, become abrupt (non-local), period-doubling cascades are truncated, and many periodic windows disappear from the chaotic regime. Saddle-node like border-collision bifurcations lead to period-tripling, period-quadrupling, and other period-multiplication process. We also consider the transitions to chaos via border-collision bifurcations on a torus. In this connection we show how the structure of the synchronization domains differ essentially from the Arnol'd tongues known for smooth systems.

References and Literature for Further Reading

- [1] H.W. Lorenz, Non-Linear Dynamical Economics and Chaotic Motion, *Lecture Notes in Economics and Mathematical Systems*, 228, Springer Verlag, Berlin (1989).
- [2] E. Mosekilde and E.R. Larsen, Deterministic Chaos in the Beer Production-Distribution System, *System Dynamics Review* 4 (1988), 131-147.

- [3] O. Sosnovtseva and E. Mosekilde, Torus Destruction and Chaos-Chaos Intermittency in a Commodity Distribution Chain, *Int. J. Bifurcation and Chaos* 7 (1997), 1225-1242.
- [4] E. Mosekilde, Topics in Nonlinear Dynamics – Applications to Physics, Biology and Economic Systems, *World Scientific, Singapore* (1996).
- [5] Zh. Zhusubaliyev and E. Mosekilde, Bifurcations and Chaos in Piecewise-Smooth Dynamical Systems, *World Scientific, Singapore* (2003).

Synchronization Phenomena in Coupled Nephrons

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The individual functional unit of the kidney (the nephron) displays oscillations in its pressure and flow regulation at two different time scales: fast oscillations associated with a myogenic dynamics of the afferent arteriole (0.15-0.2 Hz), and slower oscillations arising from a delay in the tubuloglomerular feedback (0.02-0.04 Hz). We investigate the intra- and inter-nephron entrainment of the two time-scales. Besides full synchronization, both wavelet analyses of experimental data and numerical simulations reveal a partial entrainment in which neighboring nephrons attain a state of chaotic synchronization with respect to their slow dynamics, but the fast dynamics remain desynchronized.

References

- [1] O.V. Sosnovtseva, A.N. Pavlov, E. Mosekilde, and N.-H. Holstein-Rathlou, Bimodal oscillations in nephron autoregulation, *Physical Review E*, 66 (2002) 061909(7).
- [2] A.N. Pavlov, O.V. Sosnovtseva, A.R. Ziganshin, N.-H. Holstein-Rathlou, and E. Mosekilde, Multiscality in the dynamics of coupled chaotic systems, *Physica A*, 316 (2002) 233-249.

Fidelity of Quantum Chaos

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Recently, we have witnessed a strong interest in the stability of quantum motion against small variations of the Hamiltonian characterized by fidelity. We will shortly review our theory on the behaviour of fidelity decay in different regimes characterized with several time-scales. It will be explained how the fidelity can be computed in terms of time-correlation function of the generator of perturbation. Interesting application of our ideas for the enhancement of the stability of quantum computation will be discussed in the end.

References and Literature for Further Reading

- [1] T. Prosen and M. Žnidarič, Stability of quantum motion and correlation decay, *Journal of Physics A: Mathematical & General* **35** (2002) 1455-1481.
- [2] T. Prosen and M. Žnidarič, Can quantum chaos enhance the stability of quantum computation?, *Journal of Physics A: Mathematical & General* **34** (2001) L681-L687.
- [3] T. Prosen, General relation between quantum ergodicity and fidelity of quantum dynamics, *Physical Review E* **65** (2002) 036208.
- [4] T. Prosen and T. H. Seligman, Decoherence of spin echoes, *Journal of Physics A: Mathematical & General* **35** (2002) 4707-4727.
- [5] M. Žnidarič and T. Prosen, Fidelity and purity decay in weakly coupled composite systems, *Journal of Physics A: Mathematical & General* **36** (2003) 2463-2481.
- [6] T. Prosen, T. H. Seligman and M. Žnidarič, Evolution of entanglement under echo dynamics, *Physical Review A* **67** (2003) 042112.

Misleading Signatures of Chaos in Quantum Systems

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One of the most important signatures of chaos in quantum systems is the behaviour of energy level fluctuations. The spectra of integrable systems behave as uncorrelated sequences of energy levels, while for chaotic systems correlations lead to spectral rigidity. It is conjectured that these features are universal, but before we can study them it is necessary to remove the secular trend of the spectrum, which is not universal but characteristic of each system.

The standard procedure to separate the smooth and fluctuating parts of a spectrum is called *unfolding*. Although this procedure is straightforward for some simple systems, like billiards, whose average level density is well known, it can be a very difficult task for many other systems. It is shown that some general methods, which are used when the average level density is not well known, can introduce some spurious effects or even destroy the long-range correlations, producing some features that can be easily misunderstood as an excess of spectral rigidity or as Berry's saturation (which is related to the behaviour of the classical analog of the system) [1].

Work in progress indicates that more sophisticated methods can also produce spurious effects, but a criterion can be introduced to select the best unfolding procedure.

References

- [1] J. M. G. Gómez, R. A. Molina, A. Relaño and J. Retamosa, Misleading signatures of quantum chaos, *Phys. Rev. E* **66**, 036209 (2002).

Randomness of Classical Chaotic Motion

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I shall discuss some new universal aspects of diffusion in classical deterministic and chaotic dynamical systems, especially in Hamiltonian systems. First ergodic (fully chaotic) systems will be discussed, and then the mixed type systems with a typical KAM scenario. Some generalizations by treating the correlations will be presented. Finally, I shall explain the relevance of these studies in the context of problems in stationary quantum chaos, namely the structure of stationary eigenfunctions and the statistical properties of the energy spectra.

References and Literature for Further Reading

- [1] M. Robnik, J. Dobnikar, A. Rapisarda, T. Prosen and M. Petkovšek, New universal aspects of diffusion in strongly chaotic systems *Journal of Physics A: Mathematical & General* **30** (1997) L803-L813.
- [2] T. Prosen and M. Robnik, General Poissonian model of diffusion in chaotic components, *Journal of Physics A: Mathematical & General* **31** (1998) L345-L353.
- [3] M. Robnik, T. Prosen and J. Dobnikar, Multi-component random model of diffusion in chaotic systems, *Journal of Physics A: Mathematical & General* **32** (1999) 1147-1162.
- [4] M. Robnik, Topics in quantum chaos of generic systems, *Nonlinear Phenomena in Complex Systems* (Minsk) **1** No. 1 (1998) 1-22.
- [5] T. Prosen and M. Robnik, Intermediate $E(k, L)$ statistics in the regime of mixed classical dynamics, *Journal of Physics A: Mathematical & General* **32** (1999) 1863-1873.
- [6] J. Malovrh and T. Prosen, Spectral statistics of a system with sharply divided phase space, *Journal of Physics A: Mathematical & General* **35** (2002) 2483-2490.

Time-Reversible Systems of Differential Equations

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One relatively simple, but important kind of symmetry in differential equations is the so-called time-reversibility. Namely, the system

$$\dot{u} = -v + U(u, v), \quad \dot{v} = u + V(u, v) \quad (1)$$

is called *time-reversible* if it is invariant under a rotation

$$\begin{pmatrix} u_1 \\ v_1 \end{pmatrix} = \begin{pmatrix} \cos \varphi & -\sin \varphi \\ \sin \varphi & \cos \varphi \end{pmatrix} \begin{pmatrix} u \\ v \end{pmatrix}$$

and the time inversion $t \rightarrow -\tau$.

In the talk we present an algorithm to find all time-reversible systems (1) for the case when U and V are arbitrary polynomials of the degree n .

References

- [1] A. Jarrah, R. Laubenbacher, V. G. Romanovski, The Sibirsky Component of the Center Variety of Polynomial Differential Systems, *J. Symb. Comput.* **35** (2003) 577-89.
- [2] K. S. Sibirsky, "An introduction to the algebraic theory of invariants of differential equations" *Shtiintsa, Kishinev* (1982), (Russian, English translation: *Manchester Univ. Press*, New York (1988)).

Controlling Synchronization by Delayed Feedback

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We consider two problems of synchronization control by delayed feedback. First, we study the impact of the feedback on the coherence of noisy and chaotic oscillators. We demonstrate numerically that the coherence of a noisy or chaotic self-sustained oscillator can be efficiently enhanced or suppressed, depending on the parameters of the feedback. We develop the theory of this effect, considering noisy systems in the Gaussian approximation. We obtain a closed equation system for the phase diffusion constant and the mean frequency of oscillation. For weak feedback and strong noise the theory is in a good agreement with the numerics. Next, we show that feedback induced change of the coherence directly influences the ability of the system to be synchronized; therefore the delayed feedback can be used as a tool to control synchronization process. Second, we consider the possibility of controlling synchronization transition in an ensemble of globally coupled oscillators or maps. We demonstrate that the delayed feedback is effective in this case as well: depending on the parameters, collective synchrony in an ensemble can be either enhanced or suppressed.

References and Literature for Further Reading

- [1] A. Pikovsky, M. Rosenblum, J. Kurths, Synchronization. A Universal Concept in Nonlinear Sciences, *Cambridge University Press* (2001).
- [2] D. Goldobin, M. Rosenblum, A. Pikovsky, Controlling Oscillator Coherence by Delayed Feedback, *accepted for publication in Physical Review E, in press.*

Difference Schrödinger Operators for Harmonic Oscillators on a Unitary Lattice

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The formalism of raising and lowering operators is developed for the difference operator analogue of a quantum harmonic oscillator which acts on functions on a discrete support. The grid under consideration is a mixed version of an equidistant lattice and a q -linear grid. Several properties of the grid are described. The grids under consideration are referred to by the name unitary linear lattices. The ladder difference operators are derived and compared with the continuum situation. The arising spectral problems for these operators are dealt by using the theory of bilateral Jacobi operators in weighted $l^2(\mathbb{Z})$ spaces. Eventual applications to mathematical physics and numerical Schrödinger theory are briefly discussed.

References and Literature for Further Reading

- [1] R. N. Álvarez, D. Bonatsos and Yu. F. Smirnov, q -Deformed vibron model for diatomic molecules, *Physical Review A*. 50 (1994) 1088-1095.
- [2] R. Askey, S. K. Suslov, The q -harmonic oscillator and the Al-Salam and Carlitz polynomials, *Letters in Mathematical Physics* 29 (1993) No. 2, 123-132.
- [3] N. M. Atakishiyev, S. K. Suslov, A realization of the q -harmonic oscillator, *Theoret. and Math. Phys.* 87 (1991) No. 1, 442-444.
- [4] C. Berg, M.E.H. Ismail, Q -Hermite polynomials and classical orthogonal polynomials, *Can. J. Math.* 48 (1996) 43-63.
- [5] C. Berg, A. Ruffing, Generalized q -Hermite Polynomials, *Communications in Mathematical Physics* **223** (2001) 1, 29-46.
- [6] A. Ruffing, J. Lorenz, K. Ziegler, Difference Ladder Operators for a Harmonic Schrödinger Oscillator Using Unitary Linear Lattices, *Journal of Computational and Applied Mathematics* 153 (2003), 395-410.

Formation and Dynamics of Soliton Trains in Bose-Einstein Condensates

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We study the formation of bright solitons in a Bose-Einstein condensate of 7Li atoms induced by a sudden change in the sign of the scattering length from positive to negative, as reported in a recent experiment [1]. The numerical simulations are performed by using the 3D Gross-Pitaevskii equation (GPE), a nonlinear Schrödinger equation that accurately describes the macroscopic wavefunction of the Bose-Einstein condensate [2]. We show that a number of bright solitons is produced and this can be interpreted in terms of the modulational instability of the time-dependent macroscopic wave function of the Bose condensate. In particular, we derive a simple analytical formula for the number of solitons that is in good agreement with the numerical results of 3D GPE. By investigating the long time evolution of the soliton train [3] we find that adjacent solitons repel each other due to their phase difference. In addition, we show that during the motion of the soliton train in an axial harmonic potential the number of solitons changes in time and the density of individual solitons shows an intermittent behavior. Such a complex dynamics explains the missing solitons frequently found in the experiment.

References and Literature for Further Reading

- [1] K.E. Strecker, G.B. Partridge, A. Truscott, and R.G. Hulet, Formation and propagation of matter-wave soliton trains, *Nature* 417 (2002) 150.
- [2] E.P. Gross, Structure of a quantized vortex in boson systems, *Nuovo Cimento* 20 (1961) 454, L.P. Pitaevskii, Vortex lines in an imperfect Bose gas, *Sov. Phys. JETP* 13 (1961) 451.
- [3] L. Salasnich, A. Parola, and L. Reatto, Bose condensate bright solitons under transverse confinement, *Phys. Rev. A* 66 (2002) 043603.

Particle-Wave Duality in Mesoscopic Chaotic Transport

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Two mesoscopic transport phenomena are used to probe the crossover from indeterministic wave dynamics to deterministic particle dynamics in the semiclassical limit $\hbar \rightarrow 0$. The crossover depends on the relative size of the dwell time t_{dwell} in the mesoscopic sample and the Ehrenfest time t_{Ehr} for the spreading of a wave packet. The first probe is shot noise, which gradually vanishes in the quantum-to-classical crossover since transport becomes deterministic for $t_{\text{Ehr}} > t_{\text{dwell}}$. Secondly, the induced excitation gap in proximity to a superconductor gradually closes in this crossover, since the distribution function of characteristic dwell times itself undergoes a transition.

References and Literature for Further Reading

- [1] H. Schomerus, C.W.J. Beenakker, Excitation Spectrum of Andreev Billiards with a Mixed Phase Space, *Physical Review Letters* 82 (1999) 2951-2954.
- [2] H.-S. Sim, H. Schomerus, Shot Noise in Ballistic Quantum Dots with a Mixed Classical Phase Space, *Physical Review Letters* 89 (2002) 066801.
- [3] R.G. Nazmitdinov, H.-S. Sim, H. Schomerus, I. Rotter, Shot noise and transport in small quantum cavities with large openings, *Physica Review B* 66 (2002) 241302(R).
- [4] Ph. Jacquod, H. Schomerus, C.W.J. Beenakker, Quantum Andreev map: A paradigm of quantum chaos in superconductivity, *accepted for publication in Physical Review Letters, in press; cond-mat/0212522* (2003).
- [5] J. Tworzydło, A. Tajic, H. Schomerus, C.W.J. Beenakker, Dynamical model for the quantum-to-classical crossover of shot noise, *cond-mat/0304237* (2003).

Random Matrix Theory and Arrival Statistics of Buses in Several Mexican Cities

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We analyze statistical properties of the city bus transport in several Mexican cities and show that the bus arrivals display probability distributions conforming those of the Unitary Ensemble of random matrices. We present also a modified Nagel Schreckenberg cellular automaton that successfully simulates this type of behavior.

References and Literature for Further Reading

- [1] D. Helbing, Traffic and related self-driven many-particle systems, *Rev. Mod. Phys.* **73** (2001), 1067 – 1141.
- [2] P. Seba and M. Krbalek: Statistical properties of the city transport in Cuernavaca (Mexico) and random matrix ensembles, *J. Phys. A* **33** (2000), L229 – L234.
- [3] K. Nagel and M. Schreckenberg, “A cellular automaton model for freeway traffic”, *J. Physique I* **2** (1992), 2221.
- [4] D. Chowdhury, L. Santen and A. Schadschneider, “Statistical physics of vehicular traffic and some related systems”, *Physics Reports* (329) 4-6 (2000), 199-329.

Inferring Parameters of Coupled Oscillators

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The work is based on the idea that the cardiovascular system can be modelled as a set of coupled oscillatory systems. The starting point is that signals derived from the human cardiovascular system (CVS) are exceptionally complex, being time-varying, noisy, and of necessarily limited duration. Yet an appropriate analysis of them may be expected to yield detailed information about the dynamics of the underlying physiological processes.

In our new approach, the conditional probability is obtained by expressing it in terms of a white noise path integral. Taking advantage of this idea, we have derived a concise and fast iterative Bayesian inference scheme. The proposed inference technique does not just filter out the dynamical information from noisy time series. Rather, it *uses the internal noise in the system to infer dynamical information*. That is why the internal noise in the system is actually an advantage for inference. This same technique can be applied to the N -dimensional case to provide us with parameters for the oscillatory components of CVS variability in different frequency ranges. The preliminary application to the measured CVS oscillations will be presented which confirms the appropriateness of developing a stochastic nonlinear model.

References

- [1] A. Stefanovska and M. Bračič, Physics of the human cardiovascular system, *Contemporary Physics* 40 (1999) 31–35.
- [2] A. Stefanovska, M. Lotrič Bračič, S. Strle and H. Haken, The cardiovascular system as coupled oscillators?, *Physiological Measurement* 22 (2001) 535–550.
- [3] A. Stefanovska, D.G. Luchinsky and P. V. E. McClintock, Modelling couplings among the oscillators of the cardiovascular system, *Physiological Measurement* 22 (2001) 551–564.
- [4] P. V. E. McClintock and A. Stefanovska, Noise and determinism in cardiovascular dynamics, *Physica A* 314 (2002) 69–76.
- [5] V. N. Smelyanskiy, D. A. Timucin, D. G. Luchinsky, A. Stefanovska, A. Bandyrovskyy and P. V. E. McClintock, Time-Varying Cardiovascular Oscillations, in N. S. Namachchivaya and Y. K. Lin eds. *Nonlinear Stochastic Dynamics*, (proceedings of the IUTAM Symposium in Allerton Park, University of Illinois, Urbana, August 2002), Kluwer, Amsterdam, in press.

Fidelity of the Perturbed Classical Evolution

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The stability of the evolution of Hamiltonian systems under the influence of a static perturbation attracted substantial attention recently, especially in the field of quantum computing. The main question is, how does the type of dynamics affect the divergence of the evolution of two slightly different systems. In our work we focused on classical dynamics. We compared the Liouville evolution of classical phase space densities in the original and the perturbed system, starting from the same initial condition. The overlap of the two evolved phase space densities is what is called classical fidelity. We studied both chaotic and integrable systems. In chaotic systems the initial decay of the classical fidelity is exponential and given by the Lyapunov exponent. In our work, however, we focused on the asymptotic behaviour. It turns out that the asymptotic decay in chaotic systems can be related to the decay of correlations. This means that asymptotically the decay of fidelity can be either algebraic or exponential, where in the latter case the decay rate is not necessarily related to the Lyapunov exponent. In the integrable case the initial decay of fidelity turns out to be mildly surprising as it can sometimes be even faster than exponential, while in the other case the initial decay is algebraic in nature. In our work we analytically showed that the type of decay depends on the shape of the perturbation but not its size. The fast type of decay can be related to the change of the frequency and therefore results in a ballistic divergence of the evolutions in the two systems, while the algebraic decay can be related to the perturbation of the shape of the tori.

References

- [1] Giuliano Benenti, Giulio Casati and Gregor Veble, Stability of classical chaotic motion under a system's perturbations, preprint [nlin.CD/0208003](#)
- [2] Giuliano Benenti, Giulio Casati and Gregor Veble, Decay of the classical Loschmidt echo in integrable systems, preprint [nlin.SI/0304032](#)

Multiscaling of Noise-Induced Parametric Instability

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The statistics of the exponential growth rate, which describes the parametric instability of the random frequency oscillator, is investigated. We show that in general the fluctuations of local Lyapunov exponents are non-Gaussian and demonstrate multiscaling. Analytical calculations of the generalized Lyapunov exponents are complemented with approximative and numerical results; this allows us to identify the parameter range where the deviations from the Gaussian statistics become important.

References and Literature for Further Reading

- [1] R. Zillmer, A. Pikovsky, Multiscaling of noise-induced parametric instability, *accepted for publication in Phys. Rev. E* in press
- [1] H. Schomerus, M. Titov, Statistics of finite-time Lyapunov exponents in a random time-dependent potential, *Phys. Rev. E* 66 (2002).
- [2] G. Paladin, S. Vaienti, Looking at equilibrium measures in dynamical systems, *J. Phys.* A21 (1988) 4609.
- [3] I. M. Lifshitz, S. A. Gredeskul, L. A. Pastur, Introduction to the theory of disordered systems, Wiley, New York (1988).

Stability of Quantum and Classical Dynamics: The Case of Zero Average Perturbation

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In order to compare classical mechanics with quantum the former must be formulated in a probabilistic way as a propagation of densities in phase space. Stability can then be measured by a fidelity, which is the overlap between states obtained from the same initial condition under two slightly different evolutions. This approach has been first used by Peres. Recently we studied fidelity in quantum and classical setting and found out that the two can behave completely differently. For chaotic systems the quantum fidelity decays more slowly the more chaotic the system is - just opposite to the classical fidelity. In regular systems two cases can arise: (i) the average perturbation is nonzero and (ii) the average perturbation is zero. In the first case the fidelity is dominated by a separation of perturbed and unperturbed packets and is the same for classical and quantum dynamics. In the second case, the classical fidelity decays as a power law but on the same time scale as for non-zero average perturbation. On the other hand, quantum fidelity decays on a much longer time scale if the average perturbation is zero. By having regular dynamics and zero average perturbation quantum mechanics therefore enables us to achieve longer stability times as it would be possible merely by classical mechanics.

References

- [1] A. Peres, *Quantum Theory: Concepts and Methods*, (Dordrecht: Kluwer) 1995.
- [2] T. Prosen and M. Žnidarič, Stability of quantum motion and correlation decay, *J. Phys. A* 35 (2002) 1455-1481.
- [3] T. Prosen, T. H. Seligman and M. Žnidarič, Theory of quantum Loschmidt echoes, *preprint quant-ph/0304104*.

PREVIOUS CONFERENCES

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The co-organization was provided by

Heinz Müller, Mayor of Bexbach
Dr. Volker Ostheimer, University of Saarbrücken
Professor Dr. Marko Robnik, CAMTP,
University of Maribor, Slovenia

SOCIAL EVENT FRIDAY 27 October 2000

A. Ruffing

Reception for all Participants at Hotel Hochwiesmühle

Welcome Remarks

09:30-10:00

The welcome session is directly opening the day's presentation of the Saar region and the Euroregion Saar-Lorraine-Luxembourg. We will learn about this European core region during our day's trip:

Departure of Minibus at Hotel Hochwiesmühle

10:00

Trip across the green face of Saarland to Saarbrücken

Saarbrücken is the capital of Saarland, owning a well-known university with outstanding contributions to modern computer science. The Max-Planck Institute for Computer Science is located in Saarbrücken. Saarbrücken has turned more and more into a cultural metropole of the so-called "Saar-Lor-Lux region".

Trip from Saarbrücken across the industrial face of Saarland to the World Cultural Heritage Monument "Saarhütte" in Völklingen

Völklingen is a worldwide acknowledged monument of technological history.

Trip from Völklingen along river Saar to Schengen

Lunch break near Schengen

12:30-14:00

Schengen is the famous village where the European declaration about dropping the mutual border controls of its member states has been signed. It is located at the river Mosel/Moselle, close to the triangle point between France, Germany and Luxembourg.

Trip from Schengen through Lorraine (France) to Spicheren

Spicheren is - after its crucial meaning in the past - nowadays referred to as the "Village of Peace", reminding its visitors of a great historical challenge - establishing a free and modern Europe. The memorial place in Spicheren with its cross symbol is directly located at the French-German borderline.

Trip from Spicheren to Strasbourg

Strasbourg is the terminal of our trip, the truly European town with its German-French culture. The freely elected European Parliament is at home in Strasbourg. This town is often called "Capital of the European Union" and may have an increasing meaning as a future birth place of a common European constitution.

Dinner in Strasbourg

18:30-20:30

After dinner, Reise Stolz (The "StolzPaul Bus") will take us again back to Bexbach where our colloquium BCS 2000 will start the very next morning.

SATURDAY 28 October 2000

A. Ruffing / C. Lindemann / M. Robnik <i>Introduction to the Colloquium</i>	09:15-09:30
Y. Aizawa (<i>Tokyo</i>) <i>Kinetic Laws of Cluster Formation and Evaporation of a Cluster</i>	09:30-10:00
M. Robnik (<i>Maribor</i>) <i>Aspects of Quantum Chaos</i>	10:15-11:15
COFFEE BREAK (<i>including press reception</i>)	11:15-11:45
G. Casati (<i>Como</i>) <i>Relaxation and Fluctuations in Quantum Chaos</i>	11:45-12:45
H. Markum (<i>Vienna</i>) <i>Quantum Chaos in Physical Systems</i> <i>From Super Conductors to Quarks</i>	13:00-14:00
LUNCH BREAK	14:00-15:30
T. Roubíček (<i>Prague</i>) <i>Microstructure in Micromagnetics and its Evolution Models</i>	15:30-16:00
M. Kružík (<i>Bonn</i>) <i>Variational Models for Microstructures in Shape Memory Alloys</i>	16:15-16:45
COFFEE BREAK	16:45-17:15
C. Kober (<i>Berlin</i>) <i>Composite Material with Shape Memory Alloy fibers</i>	17:15-17:45
P. Krejčí (<i>Berlin</i>) <i>Hysteresis Operators and Rate-Independent Memory</i>	18:00-18:30
A. Ruffing (<i>Munich</i>) <i>On Some Special Function Types in Nonlinear Analysis</i>	18:45-19:15
DINNER	20:00-21:00
Formation of Discussion Groups	21:00-00:00

SUNDAY 29 October 2000

H. Müller <i>Speech by the Mayor of Bexbach</i>	10:00-10:15
M. Cvetič (<i>Philadelphia</i>) <i>Gravitational and Particle Physics in M-Theory</i>	10:15-11:15
COFFEE BREAK	11:15-11:30
L. Salasnich (<i>Milano</i>) <i>Degenerate Quantum Gases and Bose-Einstein Condensation</i>	11:30-12:30
LUNCH BREAK	12:30-14:00
R. Mir-Kasimov (<i>Dubna</i>) <i>Space Quantization and Relativistic Dynamics</i>	14:00-15:00
Y. Aizawa (<i>Tokyo</i>) <i>Dynamical Models of Cellular Slimemold Dictyostelium Discoideum</i>	15:15-15:45
H. Grushevskaya (<i>Minsk</i>) <i>Spin-Polarization Corrections in Relativistic Scattering Theory of Leaky Packed Solids</i>	16:00-17:00
COFFEE BREAK	17:00-17:30
V. Romanovski (<i>Maribor</i>) <i>Algebraic Methods for Qualitative Investigation of Polynomial Dynamical Systems</i>	17:30-18:30
G. Krylov (<i>Minsk</i>) <i>On Solvable Potentials for One Dimensional Schrödinger and Diffusion Equations</i>	18:45-19:45
A. Ruffing / V. Ostheimer <i>Closing Remarks</i>	19:45-20:00
BANQUET	20:30-00:00

EAS CONFERENCE 2

OTOČEC 2001

“New Trends in Nonlinearity
and Noncommutativity”

The Castle Hotel of Otočec

12-15 October 2001

Grad Hotel Otočec, SI-8222 Otočec, Slovenia

<http://www.krka.si/en/zdravilisca/otocec>

The Directors of the Conference

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FRIDAY 12 October 2001

Arrival at the Castle of Otočec by 20:00, Dinner from 20:00 on

SATURDAY 13 October 2001

A. Stefanovska (<i>Ljubljana, Lancaster</i>) <i>Time-Varying Cardiovascular Oscillations</i>	09:30-10:00
M. Rosenblum (<i>Potsdam</i>) <i>Synchronization Approach to Data Analysis</i>	10:15-10:45
COFFEE BREAK	11:00-11:15
P. Tass (<i>Jülich</i>) <i>Demand-Controlled Deep Brain Stimulation Based on Stochastic Phase Resetting</i>	11:15-11:45
LUNCH BREAK	12:00-14:00
R. Pullirsch (<i>Wien</i>) <i>Quantum Chaos: Concept</i>	14:00-14:30
H. Markum (<i>Wien</i>) <i>Quantum Chaos: Supersymmetry</i>	14:45-15:15
M. Robnik (<i>Maribor</i>) <i>Eigenfunctions and Energy Level Statistics in Mixed Phase Space</i>	15:30-16:00
COFFEE BREAK	16:15-17:00
A. Ruffing (<i>München</i>) <i>On Several Properties of A Discrete q-Fourier Transform</i>	17:00-17:30
M. Simon (<i>München</i>) <i>Some Special Solutions to the Differential Equation $y'' + (ax^2 + b)y' + (cx + d)y = 0$</i>	17:45-18:15
S. Uhlig (<i>Maribor, München</i>) <i>Bound States in the Continuum - A Simple Model System</i>	18:30-19:00
DINNER	20:00-21:00
Formation of Discussion Groups	21:00-00:00

SUNDAY 14 October 2001

D. Svrtan (<i>Zagreb</i>) <i>On Two-Sided Estimates of Solutions of Some Combinatorial Nonlinear Recurrences</i>	09:30-10:00
V. Romanovski (<i>Maribor</i>) <i>Invariants of Differential Equations and Their Applications</i>	10:15-10:45
COFFEE BREAK	11:00-11:15
M. Martinis (<i>Zagreb</i>) <i>Time Operator in Conformal Quantum Mechanics</i>	11:15-11:45
LUNCH BREAK	12:00-14:00
T. Prosen (<i>Ljubljana</i>) <i>On General Relation Between Quantum Ergodicity and Fidelity of Quantum Dynamics</i>	14:00-14:30
S. Meljanac (<i>Zagreb</i>) <i>Common Algebraic Structure of the Chern-Simons Matrix Model and of the Calogero Model</i>	14:45-15:15
COFFEE BREAK	15:30-16:30
M. Vraničar (<i>Maribor</i>) <i>Experimental Studies of Microwave Resonators In Context of Quantum Chaos</i>	16:30-17:00
G. Veble (<i>Maribor</i>) <i>Studies in Quantum Chaos</i>	17:15-17:45
Evaluation of the Conference	18:30-19:30
DINNER	20:00-21:00
Formation of Discussion Groups	21:00-00:00

MONDAY 15 October 2001

Common Farewell Breakfast

EAS CONFERENCE 3

TRAKOŠĆAN 2002

**“Nonlinearity, Noncommutativity
and Applications”**

Hotel Coning at Trakošćan Castle

9-12 May 2002

Hotel Coning, HR-42254 Trakošćan, Croatia

<http://hotel.hr/coning/>

The Directors of the Conference

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