CAMTP

”Let’s Face Chaos through Nonlinear Dynamics”

8th International Summer School/Conference

at the University of Maribor

26 June - 10 July 2011

Dedicated to the 65th Birthday of Professor Predrag Cvitanović

Maribor **Slovenia**

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Foreword

The series of by now traditional international Summer Schools/Conferences "Let's Face Chaos through Nonlinear Dynamics" began in the year 1993 on the initiative of a group of undergraduate students of the various faculties at the University of Ljubljana, under the leadership of Mrs. Maja Malus, a student of electrical engineering at the time (now a medical doctor at Harvard), under the scientific guidance of Professors Marko Robnik, Aneta Stefanovska and Igor Grabec. Since 1996 the Schools/Conferences are held exclusively at the University of Maribor, under the organization of CAMTP - Center for Applied Mathematics and Theoretical Physics, every three years. This year we have 41 invited lecturers, most of them are leaders in this sphere of science, and 30 other participants from all over the world, from four continents, many of them from the world top groups, and quite a few of them being successful young PhD researchers. Also, according to the richness of the scientific and cultural programme, it is probably one of the best, as you can see in the following pages of this Book of Programme.

The character of our Schools/Conferences is strongly international. The profile of the School/Conference is strongly interdisciplinary, with the focus on the rich variety of problems in nonlinear science, in mathematics, natural sciences and engineering in the field of chaos, synergetics and theory of complex systems, but physics is by far the most important discipline. As for the scientific level we believe that we are gathering the worldwide leadership and elite, not only among the invited speakers, but also quite pronounced in the other participants, most of them are very talented and productive young scientists from some of the best research groups in the world. So, our gatherings in Maribor have the following dimensions: High level science, internationality, interdisciplinarity, special attention to young students and scientists, promoting them and also helping them financially (especially for those coming from financially weak countries), and finally the cultural dimension which ties together science and life, in a cosmopolitan spirit in mutual respect of all cultures of the world. The Science is something special, it is the Culture of the World, a universal culture indeed, like music.

As the main organizer of the Schools/Conferences, I have made every effort to make your stay in Maribor scientifically as profitable as possible, also culturally as much enjoyable as possible, hoping that you will not only acquire new knowledge, but also successfully present your own research work, and make new scientific collaborative links and creative friendships. This is the most important face of the Maribor gatherings, highly successful and appreciated so far.

I should like also to emphasize the personal component of the 8th School/Conference, namely the fact that it is dedicated to the 65th birthday of Professor Predrag Cvitanović (born on 1 April 1946), from Georgia Institute of Technology, Atlanta, USA. We feel honoured by his attending of our Schools and Conferences since 1999, by the fact that he accepted our invitation to act as Honorary Director, along with the four other distinguished scientists and colleagues, namely Professors Giulio Casati of Como, Theo Geisel of Göttingen, Siegfried Grossmann of Marburg and Hermann Haken of Stuttgart. Our Schools/Conferences have been dignified by the presence of Professor Predrag Cvitanović, and his lecturing already since the year 1999 (4th School/Conference). Professor Predrag Cvitanović's contributions to science are immense and brilliant. He, as a great educator, has always paid a special attention to young people and supported them strongly. He is one of the initiators of the nonlinear science and of the physics of complex systems. His main contributions are in the field of classical and quantum chaos, statistical physics, theory of turbulence, and much more. His brilliant scientific contributions to this field of theoretical physics are of permanent value and are appreciated by all generations of scientists. We consider it a privilege to celebrate his 65th birthday at our 8th School/Conference, enjoying the opportunity to thank him sincerely for his great work and contributions to science and culture. Science is the universal culture, it is indeed Culture of the World. We look forward to our gathering in Maribor 2011 to cheerfully celebrate Professor Predrag Cvitanović's 65th birthday and to review his enormous scientific life opus and his current research work. It is on Tuesday 5 July 2011, at 21:00 hours, that we shall start the official celebration of his 65th birthday by a chamber music concert, performed by the very young Slovenian piano trio "Infinitum", followed by a celebration and reception in the Kazinska dvorana of the Slovenian National Theatre in Maribor.

Professor Predrag Cvitanović

Last but not least, I should thank all the Members of the international Organizing Committee for their support and help: The Honorary Directors Giulio Casati, Predrag Cvitanović, Theo Geisel, Siegfried Grossmann and Hermann Haken, and the Members: Yoji Aizawa, Tokyo, Tassos Bountis, Patras, Dean Korošak, Maribor, Tomaž Prosen, Ljubljana, Valery Romanovski, Maribor, Andreas Ruffing, Munich and Aneta Stefanovska, Lancaster. Among the local organizers my very special thanks go again to coworkers at CAMTP, namely Dr. Janez Kaiser for his help in setting up the home pages and Mr. Benjamin Batistić for lots of technical work in preparing the information and the programme books.

Our special gratitude must be acknowledged to our respected general sponsors: The Slovenian Research Agency ARRS, Ministry of Higher Education, Science and Technology of the Republic of Slovenia, the University of Maribor represented by the Rector Professor Danijel Rebolj, the City of Maribor, represented by the Mayor of the Town, Mr. Franc Kangler, GEN Energija and ELES Slovenija.

At the very end, thanks go to all participants for coming to Maribor and contributing to a traditionally productive and enjoyable friendly scientific atmosphere.

I wish you all a scientifically successful and culturally pleasant stay in Maribor, and of course, please enjoy the Maribor Festival Lent 2011, the fireworks, and all the cultural programme, the concerts, the mountains, the excursions and trips, the Slovenian cuisine and wines.

Professor Dr. Marko Robnik
— Director of **CAMTP** —
— Director General of the Summer School/Conference —

Maribor, 12 June 2011

1st Week: 27 June - 2 July

	MONDAY 27 June	TUESDAY 28 June	WEDNESDAY 29 June	THURSDAY 30 June	FRIDAY 1 July	SATURDAY 2 July
Chairman	*Robnik*	———	———	———	———	*Chairman: Cvitanović*
09:00 - 10:00	**Cvitanović**	**Cvitanović**	**Cvitanović**	**Cvitanović**	**Cvitanović**	Ajisaka 09:00-09:30 Engl 09:30-09:50
10:00 - 11:00	**Stefanovska**	**Stefanovska**	**Stefanovska**	**Stefanovska**	**Stefanovska**	Chan 09:50-10:10 Batistić 10:10-10:40
11:00 - 11:30	– COFFEE & TEA –					Ilievski 10:40-11:10
11:30 - 12:30	**Prosen**	**Prosen**	**Prosen**	**Stöckmann**	**Stöckmann**	- COFFEE & TEA - 11:10-11:40
12:30 - 13:30	**Guhr**	**Guhr**	**Guhr**	**Guhr**	**Guhr**	Inubushi 11:40-12:00 Belov 12:00-12:20
13:30 - 16:00	– LUNCH –				13:30-15:15 Lunch	Krylova 12:20-12:40 Lan 12:40-13:10
Chairman	*Robnik*	*Burgdörfer*	*Toda*	*Stöckmann*	*Robnik*	Papamikos 13:10-13:40
16:00 - 17:00	**Burgdörfer**	**Gilbert**	**Zhang**	**Prosen**	15:15-16:15 **Cvetič**	
17:00 - 17:30	– COFFEE & TEA –				16:15-16:45 COFFEE & TEA	- LUNCH - 13:50-15:30
17:30 - 18:30	**Burgdörfer**	**McClintock**	**Stöckmann**	**Stöckmann**	16:45-17:45 **Prosen**	15:30-17:00 **Exc. City of Maribor**
18:30 -	18:30-18:50 Barkhofen	18:30-18:50 Ferčec	18:30-19:00 Kobayashi	18:30-18:50 Gehler	17:45-18:45 **Stöckmann**	17:00-18:00 **Wine tasting**
	19:30 **Welcome Dinner**	19:00-21:00 - DINNER -	19:15-21:00 - DINNER -	19:00-21:00 - DINNER -	19:00-21:00 - DINNER -	20:00 **Concert & Banquet**
		21:00 -23:00 **Concert & Opening**				23:45 **Fireworks**

2nd Week: 4 July - 9 July						
	MONDAY 4 July	TUESDAY 5 July	WEDNESDAY 6 July	THURSDAY 7 July	FRIDAY 8 July	SATURDAY 9 July
Chairman	*Robnik*	*Casati*	*Weidenmüller*	*Skokos*	*Mosekilde*	*Grossmann*
09:00 - 10:00	**Casati**	**Cvitanović**	**Grossmann**	**Flach**	**Tass**	**Han**
10:00 - 11:00	**Repovš**	**Dvorak**	**Harayama**	**Shudo**	**Skokos**	**Toda**
11:00 - 11:30	– COFFEE & TEA –					
11:30 - 12:30	**Daido**	**Matsushita**	**Ketzmerick**	**Weidenmüller**	**Romanovski**	**Seddon**
12:30 - 13:30	**Veble**	**Robnik**	**Krylov**	**Wunner**	12:30-13:00 **Korošak** 13:00-13:30 Gligorić	**Tribelsky**
13:30 - 16:00	– LUNCH –					
Chairman	*Prosen*	*Shudo*	*Romanovski*	*Korošak*	*Flach*	*Free Time*
16:00 - 17:00	**Marhl & Gosak**	**Richter**	**Geisel**	**Ruffing**	**Wilkinson**	
17:00 - 17:30	– COFFEE & TEA –					
17:30 - 18:00	Fregolente	Adagideli	Mitchell	Žunkovič	17:30-18:30 **Mosekilde**	**Last Dinner** 20:00
18:30 - 19:00					Takahasi	**Fireworks** 23:45
	19:00-21:00 - DINNER -	19:00-21:00 - DINNER -	20:00 **Concert**	19:00-21:00 - DINNER -	19:15-21:00 - DINNER -	
	21:00-22:00 **Solla**	21:00-24:00 **Concert** **Birthday party Cvitanović**	21:00 **Banquet**			

Cultural, Social and Touristic Events

LENT FESTIVAL 2011

During the entire period of our School and Conference there will be the international Festival Lent, offering a very rich variety of performances every evening and every night in the Lent area of Maribor, on the banks by the river Drava (medieval part of the old town).

MONDAY 27 JUNE 19:30: WELCOME DINNER

On Monday 27 June 2011 at 19:30 (thus after the dinner) we shall gather in the ART Kavarna in the Hotel PIRAMIDA, to get together and to enjoy a glass of fine Slovenian wine, followed by the dinner.

TUESDAY 28 JUNE 2011 21:00: OFFICIAL OPENING OF THE SCHOOL AND CONFERENCE WITH A CONCERT

The official opening of our 8th School and Conference will take place on Tuesday 28 June 2011 at 21:00 in the ART Kavarna in the Hotel PIRAMIDA. We begin with a chamber music concert by the String Quartet Feguš, followed by the opening addresses. After the speeches there will be a reception with some good Slovenian wines.

SATURDAY 2 JULY 2011: MARIBOR, WINE TASTING, CONCERT, BANQUET AND FIREWORKS

15:30-17:00 There will be a guided sight seeing tour through the city of Maribor, starting at Tourist Information Center (TIC) at Partizanska cesta 6, just in front of the entrance to the church called Frančiškanska cerkev.

17:00-18:00 Visit of the (huge) wine cellar of the VINAG Wine Company at Trg svobode 3 (100 meters from Grajski trg) and wine tasting programme.

20:00 We gather at the ART Kavarna of the Hotel PIRAMIDA enjoying a glass of champaign.

20:00-20:50 Concert: Mrs. Urška Orešič will play and sing for us.

20:50-23:45 Banquet

23:45-00:15 Fireworks of the Festival Lent

SUNDAY 3 JULY 2011: AN EXCURSION THROUGH SLOVENIA

On this day we organize an excursion which starts at 08:30 and we return to the residences in Maribor in the evening.

Lake Bled (in the Alps), Cave of Postojna, old town of Ljubljana, capital of Slovenia. The price is about 155 EUR per person, which includes everything, lunch and dinner, except for the drinks, and all entrance fees etc. This trip is strongly recommended to participants who are visiting Slovenia for the first time. We return to Maribor at about 23:30. If there will be less than 15 registered passengers in this trip, we shall organize another one, shorter and cheaper.

MONDAY 4 JULY 2011 21:00: PUBLIC EVENING LECTURE BY PROFESSOR SARA A. SOLLA, NORTHWESTERN UNIVERSITY, CHICAGO, USA

At 21:00-22:00 there will be a Public Evening Lecture delivered by *Professor Sara A. Solla* from Northwestern University, Chicago, USA, entitled *From neural activity to movement*.

The lecture will take place in the Lecture Hall of Hotel PIRAMIDA (amphitheatre at the underground level).

TUESDAY 5 JULY 2011: DEDICATED TO THE 65TH BIRTHDAY OF PROFESSOR PREDRAG CVITANOVIĆ, GEORGIA TECH, ATLANTA, USA

This day is dedicated to the celebration of the 65th birthday of Professor Predrag Cvitanović.

09:00-10:00 A Festive Public Lecture by Professor Predrag Cvitanović in Velika dvorana of the University Main Building at Slomškov trg 15.

21:00-22:00 A chamber music concert by the piano trio Infinitum, about 50 minutes, at Kazinska Dvorana of the Slovenian National Theatre in Maribor, at Slomškov trg, just next to the Main University Building and the cathedral. After the concert there will be addresses and speeches, followed by a reception with good Slovenian wines.

WEDNESDAY 6 JULY 2011 20:00: CONCERT AND FESTIVE DINNER

20:00 We gather at the ART Kavarna of the Hotel PIRAMIDA enjoying a glass of champaign.

20:00-20:45 Chamber music concert (Barbara Danko on violin, and Špela Kržan on flute)

20:45-23:00 Banquet

SATURDAY 9 JULY 2011: LAST DINNER AND FIREWORKS

We shall gather at 20:00 to enjoy the last informal dinner with some good wines in good atmosphere and shall admire the closing fireworks of the Festival Lent at 23:45-00:15 in the Lent area. Good bye MARIBOR 2011! See you at MARIBOR 2014.

All events except for the trips on Sunday 3 July are free of charge for all invited lecturers and for other participants of the School and Conference, as they are covered by the conference budget for the local expenses and by the participation fees.

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Giulio Casati (University of Insubria, Italy)

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Public Evening Lecture:
From neural activity to movement

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Abstracts of Invited Lectures

Regular and Chaotic Motion in the Linear and Non-Linear Schrödinger Equation

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In this lecture we compare and contrast the regular and chaotic dynamics as described by linear and nonlinear Schroedinger equations. The linear Schrödinger equation (LSE) predicts a strictly regular dynamics, yet classical particle chaos emerges from its short-wavelength (or semiclassical) limit. The non-linear Schrödinger equation (NLSE) which in the limit of weak interparticle interaction reduces to the LSE, on the other hand, features deterministic wave chaos. We have recently shown that wavepackets separate exponentially in Hilbert space allowing for the determination of a Lyapunv exponent in direct analogy to phase space trajectories of classical particles[1]. The Gross-Pitaevskii equation (GPE) describing Bose-Einstein condensate of ultracold quantum gases on the mean-field level is a prominent example of such a NLSE. The existence of wave chaos raises fundamental questions as to the stability of Bose-Einstein condensates and the validity of a mean-field description for the time evolution. After all, the GPE is only an approximation to the exact many-body Schroedinger equation which, in turn, is a LSE and thus strictly regular.

References

[1] Brezinova I et al. 2011 Phys. Rev. A **83** 043611

Dynamical chaos, Entanglement generation and Complexity of quantum motion

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Given two quantum systems how can we decide which one is more complex than the other? In classical mechanics the notion of complexity is rooted in the local exponential instability which leads to dynamical chaos. Such property is absent in quantum mechanics. Here we discuss the deep implications that chaos and entanglement have in characterizing quantum many-body dynamical complexity. Finally a classical approach to entanglement is discussed.

References

Balachandran V, Benenti G, Casati G and Gong J 2010 *Phys. Rev. E* **82** 046216.
Casati G, Resslen J and Guarneri I 2011 *Classical Dynamical Theory of Quantum entanglement* preprint

Modern String Theory and Particle Physics

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We review developments leading to the unification of string theories (M-theory), with an emphasis on particle physics implications. We introduce extended objects - Dirichlet branes - and highlight an important geometric role that these objects play in deriving particle physics from string theory. Constructions of string solutions with Dirichlet branes, that have features of the Standard Model with three families of quarks and leptons, are reviewed. We also highlight recent developments, where new stringy non-perturbative effects due to Euclidean D-brane instantons were introduced, and focus on their implications for neutrino masses and other couplings of the Standard Model.

References

Cvetič M and Halverson J 2011 "TASI Lectures: Particle Physics from Perturbative and Non-perturbative Effects in D-braneworlds," arXiv:1101.2907 [hep-th]

Blumenhagen R , Cvetič M, Kachru S and Weigand T 2009 "D-Brane Instantons in Type II Orientifolds," Ann. Rev. Nucl. Part. Sci. **59**, 269 [arXiv:0902.3251 [hep-th]]

Cvetič M, Garcia-Etxebarria I and Halverson J 2011 "On the computation of non-perturbative effective potentials in the string theory landscape: IIB/F-theory perspective," arXiv:1009.5386 [hep-th]

Blumenhagen R, Cvetič M and Weigand T 2007 "Spacetime instanton corrections in 4D string vacua: The Seesaw mechanism for D-Brane models," Nucl. Phys. B **771**, 113 [arXiv:hep-th/0609191]

Turbulence, in six easy (but unfinished) pieces

Predrag Cvitanović

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Lecture 1: Dynamics

We start with a recapitulation of basic notions of dynamics; flows, maps, local linear stability, heteroclinic connections, qualitative dynamics of stretching and mixing and symbolic dynamics.

References
Chapters "Overture" to "Cycle stability."
(all chapters refer to P. Cvitanović *et al.*, *Classical and Quantum Chaos*, `ChaosBook.org`)

Lecture 2: Periodic orbit theory

A motion on a strange attractor can be approximated by shadowing the orbit by a sequence of nearby periodic orbits of finite length. This notion is here made precise by approximating orbits by primitive cycles, and evaluating associated curvatures. A curvature measures the deviation of a longer cycle from its approximation by shorter cycles; the smoothness of the dynamical system implies exponential (or faster) fall-off for (almost) all curvatures. The technical prerequisite for implementing this shadowing is a good understanding of the symbolic dynamics of the classical dynamical system. The resulting cycle expansions offer an efficient method for evaluating classical and quantum periodic orbit sums; accurate estimates can be obtained by using as input the lengths and eigenvalues of a few prime cycles.

References
Chapters "Trace formulas" to "Cycle expansions."

Lecture 3: The best of all partitions

All physical systems are affected by some noise that limits the resolution that can be attained in partitioning their state space. For chaotic, locally hyperbolic flows, this resolution depends on the interplay of the local stretching/contraction and the smearing due to noise. Our goal is to determine the 'finest attainable' partition for a given hyperbolic dynamical system and a given weak additive white noise. That is achieved by computing the local eigenfunctions of the Fokker-Planck evolution operator in linearized neighborhoods of the periodic orbits of the corresponding deterministic system, and using overlaps of their widths as the criterion for an optimal partition. The Fokker-Planck evolution is then represented by a finite transition graph, whose spectral determinant yields time averages of dynamical observables.

References
D. Lippolis and P. Cvitanović, "How well can one resolve the state space of a chaotic map?", *Phys. Rev. Lett.* **104**, 014101 (2010); arXiv.org:0902.4269

Lecture 4: Symmetries and dynamics

Dynamical systems often come equipped with symmetries, such as the reflection symmetries of various potentials. Symmetries simplify the dynamics in a rather beautiful way:

If dynamics is invariant under a set of discrete symmetries G, the state space $\mathcal{M}$ is *tiled* by a set of symmetry-related tiles, and the dynamics can be reduced to dynamics within one such tile, the *fundamental domain* $\mathcal{M}/G$. If the symmetry is continuous, the dynamics is reduced to a lower-dimensional desymmetrized system $\mathcal{M}/G$, with "ignorable" coordinates eliminated (but not forgotten). We reduce a continuous symmetry by slicing the state space in such a way that an entire class of symmetry-equivalent points is represented by a single point.

In either case, families of symmetry-related full state space cycles are replaced by fewer and often much shorter "relative" cycles. In presence of a symmetry the notion of a prime periodic orbit has to be reexamined: it is replaced by the notion of a relative periodic orbit, the shortest segment of the full state space cycle which tiles the cycle under the action of the group. Furthermore, the group operations that relate distinct tiles do double duty as letters of an alphabet which assigns symbolic itineraries to trajectories.

References

Chapters "World in a mirror" and "Relativity for cyclists."
S. Froehlich and P. Cvitanović, "Reduction of continuous symmetries of chaotic flows by the method of slices," *Comm. Nonlinear Sci. and Numerical Simulation*, (2011) submitted; arXiv.org:1101.3037
R. Gilmore and C. Letellier, *The Symmetry of Chaos* (Oxford U. Press, Oxford 2007)

Lecture 5: Hopf's dynamical vision of turbulence

As a turbulent flow evolves, 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. In "Hopf's vision of turbulence," the long term turbulent dynamics is a walk through the space of such unstable patterns.

References

E. Hopf, "A mathematical example displaying features of turbulence," *Commun. Appl. Math.* **1**, 303 (1948)
B. Hof, C.W.H. van Doorne, J. Westerveel, F.T.M. Nieuwstad, H. Faisst, B. Eckhardt, H. Wedin, R.R. Kerswell and F. Waleffe, "Experimental demonstration of travelling waves in pipe flow," *Science* **305**, 1594 (2004)

Geometry of turbulence

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In the world of moderate Reynolds number, everyday turbulence of fluids flowing across planes and down pipes a velvet revolution is taking place. Experiments are almost as detailed as the numerical simulations, DNS is yielding exact numerical solutions that one dared not dream about a decade ago, and dynamical systems visualization of turbulent fluid's state space geometry is unexpectedly elegant.

We shall take you on a tour of this newly breached, hitherto inaccessible territory. Mastery of fluid mechanics is no prerequisite, and perhaps a hindrance: the lecture is aimed at anyone who had ever wondered why - if no cloud is ever seen twice - we know a cloud when we see one? And how do we turn that into mathematics?

References

J.F. Gibson *et al.*, "Movies of plane Couette," `ChaosBook.org/tutorials`
J.F. Gibson, J. Halcrow and P. Cvitanović, "Visualizing the geometry of state space in plane Couette flow," *J. Fluid Mech.* **611**, 107 (2008); `arXiv:0705.3957`
P. Cvitanović, E. Siminos and R. L. Davidchack, "On state space geometry of the Kuramoto-Sivashinsky flow in a periodic domain," *SIAM J. Appl. Dyn. Syst.* **9**, 1 (2010); `arXiv:0709.2944`

Dynamics of heterogeneous populations of coupled oscillators

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Large populations of coupled nonlinear oscillators have been playing crucial roles in a variety of disciplines of science and technology. Their interesting behaviors, e.g. synchronization, clustering, and spatiotemporal chaos, have been extensively studied experimentally as well as theoretically. Real populations of coupled oscillators are more or less heterogeneous in the sense that each constituent oscillator has its inherent dynamics. Of many different classes of such heterogeneous systems, particularly important is the one such that a population consists of oscillators with distributed values of a bifurcation parameter. Over the years we have been studying the behavior of one typical example of this class of heterogeneous populations, in which the system is composed of two groups of oscillators: one is the collection of spontaneous oscillators beyond a supercritical Hopf bifurcation and the other is formed by damped oscillators below it. Such a study is of significance in the context of checking the robustness of the behavior of the system against defects, for example, and has lead to discoveries of not a few novel phenomena, which include aging transitions, clustering, disorder-induced phase coherence, and so on.

The purpose of this talk is to give a brief review of these theoretical studies and present some results of our ongoing studies on a more generalized class of heterogeneous populations.

References

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Daido H and Nakanishi K 2007 *Phys. Rev. E* **75** art. no. 0562067; **76** art. no. 049901(E)
Daido H 2008 *Europhys. Lett.* **84** art. no. 10002
Daido H, Kawata N, Sano Y and Yamaguchi S 2008 *AIP Proceedings* No. 1076 33
Daido H 2009 *Europhys. Lett.* **87** art. no. 40001
Daido H 2011 *Phys. Rev. E* **83** art. no. 026209

Water delivery in the Early Solar System

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Essential for the development of life on our Earth is water. We investigate what are the reasons that water in such quantities is on the surface of our planet. The questions we need to answer in this connection are

- When the terrestrial planets formed how much was their content of water?
- Why don't we find water in the same quantities on the other terrestrial planets?
- What happended to the water when a mars-sized object hit the Earth and the Moon formed?
- What happened during the Late Heavy Bombardement (LHB)
- Where from came water after the LHB?
- What is the role of the comets from the Oort Cloud?

In this lecture we will discuss all these points more or less in detail. Although we have many interesting ideas about the water delivery no real satisfying answers can be given.

The weak password problem: chaos, criticality, and encrypted p-CAPTCHAs

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Vulnerabilities related to weak passwords are a pressing global economic and security issue. We report a novel, simple, and effective approach to address the weak password problem [1]. Building upon chaotic dynamics, criticality at phase transitions, CAPTCHA recognition, and computational round-off errors we design an algorithm that strengthens security of passwords. The core idea of our method is to split a long and secure password into two components. The first component is memorized by the user. The second component is transformed into a CAPTCHA image and then protected using evolution of a two-dimensional dynamical system close to a phase transition, in such a way that standard brute-force attacks become ineffective. We expect our approach to have wide applications for authentication and encryption technologies, as worldwide reactions suggest [2].

References

[1] T.V. Laptyeva, S. Flach, K. Kladko, arXiv:1103.6219 (2011).
[2] http://www.pks.mpg.de/ flach/html/password.html

The Nature of Temporal Fluctuations in Musical Rhythms

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When musical rhythms are performed by humans, the underlying beats are not entirely accurate in time, but deviate to a certain extent from those given by an ideal beat pattern, the deviations being a fundamental characteristic of music played by humans. Professional audio software applications therefore include a so-called 'humanizing' feature, which allows to add ('white-noise') temporal fluctuations to a given audio sequence. The nature of these fluctuations in human music, however, has never been scrutinized as yet.

We have examined the correlation properties of deviations from the exact beats for various combinations of hand, feet, and vocal performances, by both amateur and professional musicians [1]. In all cases, the interbeat intervals exhibit long-range correlations indicating that scaling laws are a generic feature of musical rhythms performed by humans. We also ask what is the role of these correlations in musical perception. Listeners showed a high preference for music with long-range correlated temporal deviations over uncorrelated humanized music. Based on these findings we have obtained patents for a novel concept of humanizing musical sequences.

References

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Order statistics and the Lyapunov spectra of some classes of high-dimensional billiard systems

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Consider a system made out of a possibly large number of identical copies of a two-dimensional dispersive billiard table and let us further assume a form of infrequent pairwise energy-preserving interaction among them. The interaction we will consider will typically be of collisional type and may therefore induce the exchange of a substantial amount of energy among the colliding pair.

The question we address is the following:

> What is the spectrum of Lyapunov exponents of such a system?

It turns out this question is closely related to a famous problem in probability theory, first addressed by Laplace in his attempt to construct an error function towards the end of the 18th century:

> What is the distribution of the ordered lengths of a fixed number of random divisions of the unit interval?

Very strong thermal convection
or
On the sensitive dependence on the experimental conditions and theoretical interpretation

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There is currently exciting progress in experimental and theoretical study of strongly driven, high Rayleigh number turbulent heat convection [1,2,3]. An unexpected and quite surprising multitude of different states has been found in high precision experiments by Ahlers, Funfschilling and Bodenschatz. These experiments even added to the longstanding mystery of differently scaling convective heat transport in two seemingly identical Rayleigh-Bénard experiments with cryogenic helium [4,5].

The emphasis of this talk is put on the ideas to physically understand and explain these multiple state observations, cf. [6], why that is possible and which the properties of the various states might be. The main idea is the varying role and dominance of the turbulent bulk flow and the boundary layer structures, being either laminar with different dominance of transport via thermal plumes or via thermal fluctuations or also turbulent, for either turbulent bulk or log-profile boundary layers of the velocity field, see [6].

References

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[3] Ahlers G January 2010 *lecture at the Euromech Colloquium in Les Houches, see www.hirac4.cnrs.fr/HIRAC4-Talks-files/Ahlers*

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Introduction to Econophysics

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At first sight, it seems a bit far–fetched that physicists work on economics problems. A closer look, however, reveals that the connection between physics and economics is rather natural — and not even new! Many physicists are surprised to hear that the mathematician Bachelier developed a theory of stochastic processes very similar to the theory of Brownian motion which Einstein put forward in 1905. Bachelier did it in the context of financial instruments, and he was even a bit earlier than Einstein. Moreover, not all physicists know that financial time series were a major motivation for Mandelbrot when he started his work on fractals. Mathematical modeling in physics and economics, in particular finance, is similar. The famous Black–Scholes theory for stock options, for example, is a beautiful application of stochastic processes, leading to a partial differential equation for the option price which is formally just a heat equation.

In the last 15 or 20 years, the physicists' interest in economical issues grew ever faster, and the term "econophysics" was coined. Econophysics developed into a recognized subject. The crucial reason for this was the dramatic improvement of the data situation, a wealth of data became available and (electronically) accessible. This is an indispensable prerequisite for theoretical physicists whose key competence is mathematical modeling based on empirical information. Moreover, complex systems moved into the focus of physics research. The economy certainly qualifies as a complex system and poses serious challenges for basic research. Simultaneously, economics started to develop into a more quantitative science. Although some economists are still sceptical and doubt that physics approaches are useful in their field, there is a growing number of economists who appreciate the long–standing competence of physicists in model building based on empirical data. From a more practical viewpoint, the need to quantitatively improve economical risk management is a driving force in econophysics. To manage risk, statistical features have to be understood and modeled. Not surprisingly, many econophysicists come from statistical physics.

This course gives an introduction to econophysics. The presentation starts from scratch, no background in economics is needed. The course consists of five lectures:

1. Basic Concepts
   We begin with explaining markets, particularly financial markets, efficiency, arbitrage and risk. Price and return distributions are shown. Simple stochastic processes are constructed and their limitations are discussed

2. Detailed Look at Stock Markets and Trading
   The limited descriptive power of standard stochastic processes is seen when carefully analyzing empirical stock market data. Concepts such as order book, market and limit orders as well as liquidity are explained. Various correlations in the time series of a given stock are studied. A much deeper understanding of stock market trading is achieved.

3. Financial Correlations and Portfolio Optimization
   In addition to the above mentioned correlations, there are also (cross) correlations between different stocks, because the companies depend on each other. Important information about markets can be obtained from them. Furthermore, they have a considerable impact on investments, more precisely on how to choose a portfolio comprising shares of different stocks. Methods to optimize such portfolios are presented. The rôle of a special kind of "noise" is discussed.

4. Quantitative Identification of Market States
   Qualitatively, it is plausible that markets can function in different states which emerge and stabilize after dramatic events. The (cross) correlations are used to quantitatively identify and extract such different market states. A particular focus is given on the still ongoing financial crisis.

5. Credit Risk
   A major reason for the present problems in the world economy was a credit crisis, that is, the failure of many individuals and companies to make promised payments. Models for credit risk are presented and evaluated in detail. It is shown that the benefit of "diversification" is vastly overestimated.

Econophysics already comprises a broad spectrum of activities. As time is limited, some of those will not be touched in these lectures. Nevertheless, the material presented in the course provides an overview of major directions in econophysics research. The field develops quickly, implying that not all of the topics in the course can be found in text books appropriate for a physics audience. Some good text books written by physicists are listed below, further literature will be given in the course.

References

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Some studies on limit cycle bifurcations for non-smooth systems

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There have been many studies on the behavior of non-smooth dynamical systems in recent years, and obtained some meaningful results. For instances, see the works [Filippov, 1988] and [Kunze, 2000] on the basic methods of qualitative theory, and [Bernardo et al., 2008] on the bifurcations in piecewise systems. Recently, Hopf bifurcations in general or some kind of non-smooth planar systems were studied, see for example [Coll et al., 2001; Du et al., 2008; Gasull and Torregrosa, 2003; Han and Zhang, 2010; Liu and Han, 2009; Yang et al., 2011; Zou et al., 2006]. In this lecture we consider a planar non-smooth system of the form

$$\dot{x} = f(x, y),\ \dot{y} = g(x, y),$$

where

$$f(x, y) = \begin{cases} f^+(x, y),\ x > 0, \\ f^-(x, y),\ x \le 0, \end{cases} \quad g(x, y) = \begin{cases} g^+(x, y),\ x > 0, \\ g^-(x, y),\ x \le 0, \end{cases}$$

and $f^\pm$ and $g^\pm$ are C^∞ functions for all $(x, y) \in R^2$. We focus on the studies of limit cycle bifurcations for the above system, including Hopf bifurcation near a focus or center, Poincaré bifurcation from a periodic annular and generalized homoclinic bifurcation.

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Fast photonic non-deterministic random bit generation using on-chip chaos lasers

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Optical random bit generation using chaos in semiconductor lasers subject to delayed optical feedback has recently been developed as a method for fast generation of non-deterministic random bit sequences, which are crucially important for secure communication and computation systems. However, the chaotic laser generators which have been realized so far use discrete optical components with fiber-optic or spatial optic techniques to obtain delayed optical feedback. Miniaturized chaotic lasers have been developed by monolithic integration of a distributed feedback laser, a passive waveguide, and a semiconductor optical amplifier, on a single chip. However, it has not yet been known whether such on-chip chaotic lasers can be applied for fast, random bit generation. We present the first monolithically integrated optical random bit generator which operates at rates up to 2.08 Gbps. Our demonstration strongly suggests potential for widespread use of fast optical random bit generation with chaotic lasers.

References

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Regular-to-Chaotic Tunneling and Spectral Statistics

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The first part of the talk will review recent work on the quest for a quantitative understanding of tunneling in systems with a mixed phase space. The focus will be on dynamical tunneling from a regular to a chaotic region. Theoretical approaches for predicting the direct regular-to-chaotic tunneling rate and the combination with resonance-assisted tunneling will be presented, with applications to microwave billiards and optical microcavities. In the second part the influence of regular-to-chaotic tunneling on spectral statistics is studied. In the regime of small spacings it will be shown analytically and numerically that the nearest neighbor level-spacing distribution follows a power law with a fractional exponent.

References

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The visibility and correlation networks of calcium dynamics in pancreatic islets

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Network theory has been successfully used in exploring the structure of many complex systems in the last decade [1]. It seems that a particular organization of biological networks is common to biological systems at all scales.

Here, we shall present the construction of complex networks of pancreatic islet, a compact microorgan in which the release of insulin is under physiological conditions robustly controlled by an efficient cell-to-cell network communication.

The networks of insulin releasing beta-cells are formed based on measured time series data of calcium dynamics and positional information obtained by image analysis of confocal multiphoton functional imaging of intact islets in pancreatic slice tissues. Using the visibility algorithm [2] we will first represent single time series as networks which will then be coupled based on correlations of the calcium dynamics in the islet. We will analyze the properties of obtained islet networks and compare them with the network model of spatially embedded heterogeneous cells [3] to seek the relationship between the structure and the function of the tissue [4].

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Solvable Models in 1D Quantum Mechanics & Stochastic Dynamics

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In the first part of the lecture I shall briefly outline main approaches to solvability in quantum mechanics. Exactly solvable problems are those admitting construction of all eigenstates of significant spectrum plus continuous spectrum (if it exists) in an analytical form. A slightly weaker form of solvability is called quasi exact solvability (QES) and is referred to problems when only a few number of eigenstates can be found analytically whereas to find other states one has to use some numerical algorithms.

Then I shall concentrate myself on 1D problems and analytical approaches to their investigations. I shall start from the construction of quasi-exactly solvable (QES) problems with one additional condition on polynomial coefficients of governing ODE imposed. Then I shall consider some new results on interesting properties of some QES problems where more than one condition are imposed. In particular the possibility of the situation when one governing equation corresponds to several quantum QES problems will be discussed.

In the second part I shall briefly present the main concepts of the SUSY quantum mechanics and the interrelation between quantum mechanics and stochastic dynamics. Few examples will be demonstrated to show quite unexpected features of the constructed stochastic dynamics solutions.

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Optimal Topologies for Best Dynamical Responses in Complex Biological Networks

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In the last three decades biological rhythms were extensively studied. New theories and experiments in the field of non-linear dynamics brought new insights into understanding of heart and EEG rhythms, our daily cycle of walking and sleeping, various metabolic processes, and many other rhythms observed at macroscopic level (Glass 2001). To understand the origins of those rhythms cellular oscillators were studied. The basic idea was to investigate cellular oscillators first, and then coupling them to see their collective effects in tissues. However, understanding the behavior of particular oscillators in a network does not necessarily mean that one could understand complex dynamics of the networks. It has been realized that functioning of tissues and organs does not only depend on intrinsic rhythms of individual cells, but it also relies on collective activity of cell populations. Rhythms essential for life are thus a result of interactions of these cells with each other in terms of intercellular communication. The many efforts devoted to understand collective phenomena in biological systems take now advantage of the recent theory of complex networks. Complex topologies such as small-world or scale-free networks have been identified in a plethora of real-life systems (Albert and Barabási 2002). The question arises how to recognize optimal network topology which under given circumstances enables best network dynamical responses. To this purpose, we employed a mathematical model of cellular networks in which we can smoothly change the topology from a scale-free network with dominating long-range connections to a homogeneous network with dominating short-range connections, where actually only adjacent cells are connected. Since biological cells exhibit diverse temporal patterns we take into account different types of inherent dynamics of individual units constituting the network, like bistable and excitable dynamics, bursting oscillations, and also non-oscillatory cellular transients. We found that irrespectively of the type of inherent dynamics, an optimal network topology exists for which the collective behavior of coupled cells provides best results. Taking into account particular examples, and studying stochastic and coherence resonance effects the best responses were obtained for networks in the mid range between scale-free and regular topology, when a suitable number of hubs and a proper ratio between long- and short-range connections exist in the networks (Gosak et al. 2010a, 2011). Our method was also applied to real experimental data obtained in airway smooth muscle cells. Two types of cells, ones characterised by normal physiological responses and the others with pathological hypoxic responses, were exposed to high concentrations of KCl and the responses at tissue level were measured. The experimental measurements cannot be explained by differences in cellular dynamics, or in another words, knowing the individual cellular dynamics is not enough to explain the responses at tissue level. On the other hand, however, we were able to explain the experimental findings by modelling the corresponding topologies responsible for particular physiological and pathophysiological responses. We found that changes in tissue topology were mainly responsible, more than changes in particular cellular dynamics, for developing of pathological behaviour in the tissue (Gosak et al. 2010b).

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Statistical Features of Complex Systems —Toward establishing sociological physics—

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Complex systems have recently attracted much attention, regardless of natural sciences or sociological sciences. Members constituting a complex system evolve through nonlinear interactions among each other. This means that in a complex system the multiplicative experience or, so to speak, history that any member has had produces its present characteristics. We can then anticipate the following. If attention is paid to any statistical property in any complex system, the lognormal distribution is the most natural and appropriate for the standard or normal statistics to look over the whole system. In fact, the lognormality emerges rather conspicuously when we examine, as familiar and typical examples of statistical aspects in complex systems, nursing-care period for the aged, populations of prefectures and municipalities, and our body height and weight. Many other examples are found in nature and society. Based on these observations, we would like to discuss the possibility of sociological physics.

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Rogue waves in superfluid ^{4}He

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We discuss recent experiments on nonlinear wave interactions in superfluid ^{4}He leading to the observation [1] of rogue waves. The equivalent phenomenon on the ocean [2] involves waves that are rare, and much higher (and steeper) than all the other waves around them. For obvious reasons, they are a menace to shipping. There have been several suggestions about possible mechanisms for the creation of rogue waves. These include the combined effects of wind and currents, and the focusing effects associated with the profile of the ocean floor and nearby shorelines. Where rogue waves appear in deep water far from any shore, which they sometimes do, it seems likely that they evolve through nonlinear interactions within the "noisy background" of smaller wind-blown waves [3]. Rogue waves have been sought experimentally and/or studied in e.g. large wave tanks, optical systems, microwave systems, and superfluid ^{4}He.

We will review briefly the necessary background in turbulence and superfluidity, discuss why superfluid ^{4}He is an ideal medium for modelling nonlinear wave interactions and wave turbulence in the laboratory [4], present our observations of rogue waves [1], and consider their implications.

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Synchronization Structure in Kidney Autoregulation

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As part of an effort to understand the relation between hypertension and kidney function we have long been engaged in the study of nephron autoregulation, i.e. the mechanisms by which the individual functional unit of the kidney regulates the incoming blood flow [1]. This regulation involves two different mechanisms: A myogenic mechanism that reacts directly to changes in the arterial pressure, and a so-called tubuloglomerular feedback (TGF) that responds to changes in the salt concentration of the fluid that leaves the nephron. Due to a delay in the feedback of about 15 sec, the TGF mechanism tends to produce large amplitude oscillations in the nephron pressures and flows with periods in the 30-40 sec range. The myogenic mechanism depends on a propensity of the smooth muscle cells in the arterial wall to contract in response to an increasing blood pressure. This mechanism involves a positive feedback and gives rise to oscillations with periods in the 6-8 sec range.

The regulatory mechanisms both work through the same smooth muscle cells. This allows the oscillatory modes to interact and to synchronize with typical locking ratios of 1:4, 1:5 or 1:6. Moreover, episodes of period-2 dynamics are observed for about 50% of the experimental time traces. The nephrons are typically arranged in pairs that share part of a common arteriole. Hence, one can also observe synchronization between neighboring nephrons both of the TGF-mediated and the myogenic oscillations.

The focus of the present study is to examine the mechanisms by which a pair of neighboring nephrons moves in and out of synchrony. It is well-known that a period-doubling cascade that unfolds along the edge of a synchronization tongue displays a special scaling behavior, referred to as cyclic or C-type criticality. Our analyses show that a different structure arises in the coupled nephron system. In particular we find that the transition from synchronized periodic dynamics to quasiperiodic dynamics involves a torus bifurcation rather than the usual saddle-node bifurcation. Moreover, each period-doubling of the stable and unstable resonance modes not only leads to a new pair of saddle-node bifurcation curves, but also to a torus bifurcation curve that extends along one of the edges of the resonance zone.

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The many-body problem far from equilibrium: Where statistical mechanics meets quantum information theory.

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In this series of lectures we shall outline the basic concepts of quantum information theory which have been either originally introduced recently, re-used extensively, or sometimes only rephrased in more general and cleaner contexts, in order to advance our understanding of equilibrium and non-equilibrium quantum statistical mechanics of low dimensional interacting many-body systems; such as *entanglement*, *renormalization*, *criticality*, *area laws*, *Markovian master equations* etc.

Our emphasis in particular will be on studies of locally interacting quantum chains (spin chains, fermionic or bosonic chains) far from equilibrium, either in time-dependent or in (non-equilibrium) steady state context. As such systems have recently become amenable to accurate and well controlled experimental treatments, in particular in the field of cold gases and optical lattices [1], whereas some related phenomena have long been debated in the community of solid state physics [2,3], we are thus witnessing exciting theoretical challenges. For example, one of the key fundamental questions in non-equilibrium statistical physics is to derive precise microscopic conditions under which non-equilibrium quantum transport is diffusive or ballistic.

The lectures will cover several fundamental theoretical problems and present the main ideas of the best current theoretical and numerical methods to tackle them. The main prototype toy models used in our numerous examples will be the (anisotropic) Heisenberg chain of spins 1/2 and the Ising chain of spins 1/2 in a tilted magnetic field.

Five topical lectures will cover the following material:

- **Lecture 1** *Basic concepts of quantum information theory in many-body systems.* [4,5] Entanglement and correlations. Area laws. Valence bond ground states and matrix product ansatz. Time-evolution of a many-body system. Trotter formula. Examples.
- **Lectue 2** *Renormalization.* [6] Renormalization group and efficient description of many-body quantum states, density matrix renormalization group. Variational and time-dependent approach. Quenched dynamics. The many-body time evolution problem: How far can we go?
- **Lecture 3** *Open quantum systems.* [7,8] Markovian master equations, Lindblad versus Redfield model. Non-equilibrium steady states. Quasi-free dynamics and its analytical description. Canonical quantization in the Liouville-Fock space. Non-equilibrium quantum phase transitions. [9,10,11]
- **Lecture 4** *Quantum transport problem.* Non-equilibrium transport from quantum master equation [12] versus linear response theory and Kubo formalism [3]. Examples of diffusive and ballistic quantum transport. The problem of spin diffusion. The relevance of integrability and conservation laws. Mazur inequality. The problem of microscopic derivation of the quantum Fourier law of heat conduction.
- **Lecture 5** *Quantum chaos in many body-systems.* The problem of quantum Loschmidt echoes and fidelity decay. [14] The relevance of quantum chaos for the transport problem and non-equilibrium phenomena. [13]

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Chaotic examples in low-dimensional topology

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During the last three decades, Slovenian research group *Topology and Geometry* has been intensively working, in collaboration with several foreign research groups from United States, Japan and Russian Federation, in various areas of geometric topology. Among the more recently studied unsolved problems are also very interesting connections between chaos theory and geometric topology. In this lecture we shall illustrate, by means of examples, how certain methods of modern geometric topology can be used to construct very interesting and diverse examples in chaos:

(i) Using a classical example from 1930's, discovered by the celebrated British topologist J. H. C. Whitehead, of an open contractible topological 3-manifold which fails to be homeomorphic to the Euclidean 3-space R^3, we shall see how the corresponding Whitehead continuum "at infinity" is not a chaotic local attractor for one common method of embedding of this continuum;

(ii) We shall show how to modify the embedding of the Whitehead continuum from (i) so that the new embedding of this continuum becomes a chaotic local attractor;

(iii) We shall review the key techniques from modern geometric topology which are needed for verification of the intriguing properties of the special embedding of the Whitehead continuum in (ii); and also list some open problems and conjectures in this interesting and quickly developing research area.

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Graphene Billiards

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As distinct from the (smooth) confinement potential of semiconductor-based lateral quantum dots, boundaries in graphene nanostructures, arising from abrupt lattice termination, are (locally) composed of zigzag- or armchair-type atomic arrangements, which for instance characterize nanoribbons and usually vary along the edges of a graphene quantum dot. Depending on the type of edge, namely zigzag or armchair, a ballistic graphene cavity can be regarded as representing a single Dirac billiard for massless fermions or two coupled copies of it, respectively. Hence the edges affect crucially the spectral and transport properties of graphene billiards. In particular, some edges cause effective time reversal symmetry breaking even if the system is literally time reversal invariant [1].

After a brief introduction into the relevant physics of graphene we develop a theoretical approach that is capable of handling such edge effects in graphene quantum dots. We will proceed in two steps. First, we derive an exact expression for the Green function of a mesoscopic graphene flake, where each term in the related expansion corresponds to the specific number of times the quasiparticle hits the edge. Second, we employ a semiclassical approximation for the Green function in the ballistic regime to derive Gutzwiller- and Berry-Tabor-type trace formulae for the energy spectra of chaotic and integrable, closed graphene systems [2]. Furthermore, we will consider the spectral statistics of chaotic graphene billiards, as well as the conductance of open quantum dots. In particular, we focus on graphene specific features in phase-coherence effects such as weak localization and universal conductance fluctuations.

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Quantum Chaos and Random Matrix Theories

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I shall present the fundamentals of quantum chaos, especially the statistical properties of energy spectra of the stationary Schrödinger equation. For Hamilton systems having the classical limit, we find in the semiclassical limit, that the spectral fluctuations obey the Poissonian statistics, whilst for classically ergodic and chaotic systems the statistics of the eigenvalues of the Gaussian random matrices applies. In both cases we have universality, as no free parameter appears. If the system is of the mixed type (generic system), having divided classical phase space (regular motion on invariant tori and chaotic motion on complementary initial conditions) we find in the strict semiclassical limit the statistical independence of regular and chaotic energy levels (Berry and Robnik 1984). This BR-picture rests upon the principle of uniform semiclassical condensation of Wigner functions (WF) of eigenstates, where we see in the semiclassical limit that WF fill uniformly the classically accessible phase space (regular WF on invariant tori, chaotic ones on the chaotic components), and the eigenvalues do not interact. At lower energies or larger values of the effective Planck constant we observe new effects, namely in the first place localization of chaotic eigenstates (nonuniform spreading of WF) and interaction of eigenvalues (due to the tunneling, i.e. overlap of semiclassical WF in classically forbidden regions). I shall present most recent models of random matrices which excellently describe these effects. Important examples are e.g. various 2D billiard systems and the hydrogen atom in strong magnetic field.

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Integrability of 3-dim Polynomial Systems of ODEs

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Integrability of systems of differential equations is one of central problems in the theory of ODEs. Although integrability is a rare phenomenon and a generic system is not integrable, integrable systems are important in studying various mathematical models, since often perturbations of integrable systems exhibit rich picture of bifurcations.

In our talk we first give some basics of the method of normal forms for autonomous systems

$$\dot{\mathbf{x}} = A\mathbf{x} + \mathbf{X}(\mathbf{x}),$$

where $\mathbf{x} = (x_1, \ldots, x_n)^T$, $X(\mathbf{x}) = (X_1(\mathbf{x}), \ldots X_n(\mathbf{x}))^T$ is an analytic vector-function whose series expansion starts from at least quadratic terms.

Then we present an efficient computational approach to find systems with first integrals within some families of polynomial systems of ordinary differential equations in the case when the matrix A of the linear approximation has one zero eigenvalue or two pure imaginary eigenvalues while the other eigenvalues have negative real parts. We apply it to find first integrals or conditions for their existence for three dimensional systems involving cubic polynomials. The procedure requires finding solutions of systems of polynomials, so we also discuss an approach to the decomposition of affine varieties using modular arithmetics.

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Quantum Difference-Differential Equations

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Differential equations which contain the parameter of a scaling process are usually referred to by the name Quantum Difference-Differential Equations. Some of their applications to discrete models of the Schrödinger equation are presented and some of their rich, filigrane und sometimes unexpected analytic structures are revealed.

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Surface Nanobubbles

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Surface nanobubbles are nanoscopic gas bubbles that form at the solid/liquid interface. They are surprisingly stable to bulk dissolution, surviving at least 11 orders of magnitude longer than the classical expectation. Here we describe a route to nucleation before providing a model for their remarkable stability. The key to the stability is that the gas in a nanobubble is of Knudsen type. This, combined with the broken symmetry created by the hard substrate and 'leaky' liquid/gas interface, leads to the generation of a bulk liquid flow which effectively forces the diffusive gas to remain local. Hence, the gas does indeed diffuse out of the nanobubble, but is trapped in this circulatory flow where it is transported back to the three-phase line for re-entry into the bubble.

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Role of natural boundaries of KAM curves in quantum tunneling problems

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Natural boundaries are borders of analyticity of functions. In the textbook of complex analysis, one can find simple concrete examples which indeed have natural boundaries, but it is in general difficult to show that an arbitrarily given function has natural boundaries. In the early 80s, natural boundaries has been discussed in conjunction with arguments on the breakup of the KAM curves in the area-preserving map. Natural boundaries have been examined there as a mathematical tool to specify the condition for the last KAM curve.

Here we discuss possible roles of natural boundaries in quantum tunneling problem. Since tunneling is purely quantum mechanical, it may be reasonable that complex classical dynamics comes into play in its description, and the recent progress of complex semiclassical technique makes it possible. The issue of natural boundaries is often mentioned from the beginning of the study of multidimensional tunneling, but still its real role is not clear enough.

Our approach to investigate this problem is (0) to link, in analogy with one-dimensional complex dynamics, natural boundaries to the Julia set which are the most relevant objects in the complex classical description of quantum tunneling, (1) the precise identification of natural boundaries using Páde approximations to observe its manifestation in quantum dynamics (2) "complexifying" a piecewise affine map in a proper manner to develop some analytical arguments on the role of natural boundaries.

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Efficient methods of chaos detection

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Determining the chaotic or regular nature of orbits of conservative dynamical systems is a fundamental problem of nonlinear dynamics, having applications to various scientific fields. The most commonly employed method for distinguishing between regular and chaotic behavior is the evaluation of the maximum Lyapunov exponent (MLE) σ_1, because if $\sigma_1 > 0$ the orbit is chaotic. The main problem of using σ_1 as a chaos indicator is that its numerical evaluation may take a long –and not known a priori– amount of time to provide a reliable estimation of the MLE's actual value. Over the years, several methods which try to avoid this problem have been introduced. In this talk we will present two such techniques, namely the smaller (SALI) and the generalized (GALI) alignment indices, which are based on the evolution of small deviations from a given orbit.

First we will recall the definition of the SALI, emphasizing its effectiveness in distinguishing between regular and chaotic motion. For the computation of the SALI one has to follow the evolution of an orbit and of two initially different unit deviation vectors from it (in contrast to the computation of the MLE where only one deviation vector is needed). The SALI is defined as the smaller norm of the vectors produced by the addition and the difference of the two evolved unit deviation vectors. The index exhibits completely different behaviors for chaotic and regular orbits, which help us distinguish between the two cases. In particular, it tends exponentially to zero for chaotic orbits, while it remains different from zero for regular ones. To illustrate the SALI's advantages we will apply it to a model of a simplified accelerator ring having sextupole nonlinearities, in order to estimate rapidly and accurately the dynamic aperture (i.e. the stability domain around the nominal circular orbit) of the system.

Then, we will focus on the GALI method. The generalized alignment index of order $k > 1$ (GALI_k), is defined as the volume of a generalized parallelepiped, whose edges are k initially linearly independent unit deviation vectors from the studied orbit. An efficient numerical scheme for the computation of the GALI, which is based on the singular value decomposition (SVD) algorithm, will be presented. We will also show analytically and verify numerically on particular examples of Hamiltonian systems and symplectic maps that, for chaotic orbits GALIs tend exponentially to zero with exponents that involve the values of several Lyapunov exponents, while in the case of regular orbits GALIs fluctuate around non-zero values or go to zero following power laws that depend on the dimension of the torus and the number of used deviation vectors. Then, exploiting their advantages we will demonstrate how one can use the GALIs for identifying quasiperiodic motion on low-dimensional tori.

Finally, we will discuss the numerical integration of the variational equations, which govern the evolution of deviation vectors in Hamiltonian systems. These equations have to be integrated simultaneously with the Hamilton's equations of motion which define the evolution of orbits. We will show how one can integrate this extended set of differential equations by the so-called '*tangent map (TM) method*', a scheme based on symplectic integration techniques. According to this method, a symplectic integrator is used to approximate the solution of the Hamilton's equations of motion by the repeated action of a symplectic map S, while the corresponding tangent map TS, is used for the integration of the variational equations. We will present a simple and systematic technique to construct TS. Then we will show that the TM method is superior to other commonly used numerical schemes for integrating the variational equations of low- and high-dimensional Hamiltonian systems, both with respect to its accuracy and its speed.

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From neural activity to movement

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The human brain has about 85 billion neurons, of which about 15 billion are part of the cortex. These cortical neurons fire action potentials (spikes) at a rate of about 10 Hz. Thus, neurons in our cortex emit about 150 billion spikes per second. This activity underlies our sensory perceptions, our thoughts, our decisions, our actions. One of the central problems of systems neuroscience is that of *decoding* these vast spatial and temporal patterns of neural activity so as to interpret them and assign meaning to them. In the last ten years, much progress has been made in decoding activity of neurons in the motor cortex, an output area of the brain that controls movement through its projection to muscles via the spinal cord. In this talk I will report on reproducible experiments carried out by several groups since 2000. These experiments are based on the implantation of multielectrode arrays that record neural activity in awake behaving monkeys. The arrays allow us to monitor the activity of about one hundred neurons in motor cortex during the execution of sequences of reaches to provided targets. I will describe our theoretical efforts to construct models that capture the underlying relationship between neural activity and movement, and thus predict the direction and extent of a reach before the movement is executed. From a theoretical point of view, these studies have allowed us to make substantial progress in our understanding of the neural code. From a practical point of view, our increasing ability to extract information from neural signals has allowed us to translate neural activity into commands to control computer cursors and robotic manipulators. The potential of this approach to restore motor behavior in severely handicapped patients motivates pioneering interdisciplinary research in Brain Machine Interfaces (BMIs), a new area at the frontier of systems neuroscience.

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Biological oscillators

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In this series of lectures we shall reconsider the long-standing question "What is life?" probably best known as formulated by Erwin Schrödinger in his book of that title.

Schrödinger's paradox is that, in a world governed by the Second Law of Thermodynamics, all closed systems are expected to approach a state of maximum disorder – but life approaches and maintains a highly ordered state, which seems to violate the Second Law. The paradox is resolved by noting that life is not a closed system. Corresponding to the increase of order inside an organism is the decrease in order outside this organism. Overall, the Second Law is obeyed, and life maintains a highly ordered state, which it sustains by continuously increasing the disorder in the Universe.

Living systems will be considered as being thermodynamically open. A continuous exchange of energy and matter is needed to maintain a living system, and this gives rise to rate processes. The rate processes result in oscillations and the time-scales on which the processes can occur are what determine the frequencies of the oscillations. Those processes which occur on a certain time scale contribute to the specific function and structure of a system that on the macroscopic scale can be considered as an entity.

In this way living matter can be considered as ensembles of oscillators that interact internally within the ensemble, and the ensembles also interact one with another. The magnitude of their activity is proportional to the level of synchronization they achieve.

Therefore, we will briefly discuss the non-equilibrium thermodynamics approach introduced by Hermann Haken and the phase dynamics approach introduced by Yoshiki Kuramoto. We will review current developments in the field – both theoretical studies of coupled ensembles of oscillators as well as methods of analysis to study properties from measured data.

First we will illustrate the concept, discussing a living cell and its function and considering the cell as an ensemble of oscillators; then we will move on to cardiovascular dynamics and then to brain dynamics. We will summarize the lecture series by arguing that a new theory of nonautonomous dynamical systems is needed in order to advance our understanding and to provide a mathematical description of living systems. We will present the state of the art for this new and fast-developing field.

The following lectures will be included –

1. Phase dynamics theory and its application to inverse problems
2. A living cell and its dynamics
3. Cardiovascular dynamics
4. Brain dynamics
5. Recent developments in nonautonomous systems.

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Quantum chaos and random matrix theory

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Random matrix theory is the standard tool to describe the universal properties of the spectra of classically chaotic systems. An overview on the existing experiments is presented, in particular from nuclear and atomic physics, mesoscopic physics, and a variety of billiard systems. On the theoretical side the basic concepts are introduced, including spectral density, level spacing distribution, two-point correlation function, spectral form factor, and related quantities. Spectral level dynamics is another important aspect, i.e. the development of the eigenvalues under the influence of an external perturbation. The course ends with an introduction into supersymmetry theory, the method of choice to perform averages over ensembles of random matrices.

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Long-lasting neuronal desynchronization caused by coordinated reset stimulation

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A number of brain diseases, e.g. movement disorders such as Parkinsons disease, are characterized by abnormal neuronal synchronization. Within the last years permanent high-frequency (HF) deep brain stimulation became the standard therapy for medically refractory movement disorders. To overcome limitations of standard HF deep brain stimulation, we use a model based approach. To this end, we make mathematical models of affected neuronal target populations and use methods from statistical physics and nonlinear dynamics to develop mild and efficient control techniques. Along the lines of a top-down approach we test our control techniques in oscillator networks as well as neural networks. In particular, we specifically utilize dynamical self-organization principles and plasticity rules. In this way, we have developed coordinated reset (CR) stimulation, an effectively desynchronizing brain stimulation technique. The goal of CR stimulation is not only to counteract pathological synchronization on a fast time scale, but also to unlearn pathological synchrony by therapeutically reshaping neural networks.

The CR theory, results from animal experiments as well as clinical applications will be presented: Animal and human data will be shown on electrical CR stimulation for the treatment of Parkinsons disease via chronically implanted depth electrodes. Furthermore, acoustic CR stimulation for the treatment of subjective tinnitus will be explained. Subjective tinnitus is an acoustic phantom phenomenon characterized by abnormal synchronization in the central auditory system. In a multicenter proof of concept study it has been shown that acoustic CR stimulation significantly and effectively counteracts tinnitus symptoms as well as the underlying pathological neuronal synchronization processes.

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Time series analysis using wavelet for molecular dynamics simulation of proteins

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A new method to extract nonstationary features of coarse grained motions is presented for time series data of molecular dynamics simulation of proteins. We use the wavelet transformation together with the singular value decomposition (SVD). The wavelet analysis enables us to characterize time varying features of the dynamics and SVD enables us to reduce the degrees of freedom of the data. We apply our method to time series data obtained by molecular dynamics simulation for Adenylate Kinase from *Escherichia coli* (AKE), and *Thermomyces lanuginosa* lipase (TLL).

For the case of AKE, we show that the first singular vector alone can describe main features of the collective motions. Moreover, time dependence of the first singular vector reveals transient features of slow collective motions both in space and frequency. Introducing quantities which characterize similarity of such transient features, we have identified several types of collective motions. As for the space, the most typical types exhibit collective movement of the domains, and the boundaries of these collective oscillations coincide with the hinges identified previously. However, more complicated features of slow motions are also revealed, which indicates that some parts of the domains exhibit separate slow oscillations. As for the frequency, we have noticed that peaks of the spectra vary as time evolves. Such time-dependence of the spectra implies importance of nonlinear effects which result in energy transfer among collective motions.

For the case of TTL, by introducing indexes to characterize collective motion of the protein, we have obtained the following two results. First, time evolution of the collective motion involves not only the dynamics within a single potential well but takes place wandering around multiple conformations. Second, correlation of the collective motion between secondary structures shows that collective motion exists involving multiple secondary structures. We discuss future prospects of our study involving "disordered proteins".

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Soft-Mode Turbulence and Symmetry

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Abstract

The soft-mode turbulence (SMT) is an unusual type of spatiotemporal chaos at onset analogous to the second order phase transitions in equilibrium systems. It was discovered in 1995-96 [1-4] and still remains an appealing issue. SMT arises as a result of a single supercritical bifurcation from a quiescent state. On one hand it exhibits typical features of developed turbulence, such as the Kolmogorov cascades (both normal and inverted), interplay of different spatiotemporal scales, decay of correlations, etc. On the other hand it is characterized by critical slowing down and divergence of the correlation length at the onset, typical to the second order phase transitions [5]. In the present contribution deep connection between SMT and the problem symmetry (including effects of weakly broken symmetry) is revealed. It is shown that the origin of SMT is in coupling of short-wavelength modes, related to a Turing type instability of spatially uniform states of the system, with slow long-wavelength modes detaching from a neutrally stable Goldstone mode, related to the problem symmetry. The symmetry violation may result in suppression of SMT, so that instead of SMT spatially periodic patterns arise. Symmetry-related constrains imposed on the the structure of the corresponding stability problems are discussed too. SMT may exhibit unusual scaling properties, which also are inspected. The developed theory is compared with experiment. Finally some open questions are indicated.

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Measure stretching exponents and cosmic ray arrival directions

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In a chaotic system, the long term stretching of the local neighbourhood of a trajectory is characterized by the Lyapunov exponent. In an ergodic system, the Lyapunov exponent is independent of the initial point, meaning that long time local stretching rates are equal everywhere. Nevertheless, when observing the stretching of some global object in phase space when evolved under the phase space flow, the long term increase of its measure is not characterized by the Lyapunov exponents but by a set of related stretching exponents that are different and typically larger than the corresponding Lyapunov exponents. I will demonstrate the origin of the discrepancy between the local and global stretching exponents and how it relates to variances in short time stretching rates.

I will then focus on the case of deterministic chaotic random maps. These can be considered as a model for cosmic rays traveling through random magnetic fields. I will demonstrate that the global length stretching exponent is the relevant quantity characterising the number of possible different directions for cosmic rays to reach a point in space (i.e. Earth) when originating from a single source.

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Fourier's Law for quasi-one-dimensional chaotic quantum systems

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We derive Fourier's law for a completely coherent quasi-one-dimensional chaotic quantum system coupled locally to two heat baths at different temperatures. We solve the master equation to first order in the temperature difference. We show that the heat conductance can be expressed as a thermodynamic equilibrium coefficient taken at some intermediate temperature. We use that expression to show that for temperatures large compared to the mean level spacing of the system, the heat conductance is inversely proportional to the level density and, thus, inversely proportional to the length of the system.

Test-tube model for rainfall

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The lack of quantitative predictions about the life cycle of clouds is one of the major obstacles to properly account for the earth albedo in climate models. A central problem is the 'condensation-coalescence bottleneck' of the growth of intermediate size droplets (see, for example, Shaw, 2003, Falkovich, Fouxon and Stepanov, 2002). Recent work addresses this problem by measurement campaigns in clouds, large-scale laboratory models, and high performance computing. Here we suggest a complementary approach by using the universality of hydrodynamic equations to map the problem to a test-tube setting. We model droplet growth by a period of Ostwald ripening, which is treated using the approach of Lifshitz and Slezov (1961), followed by a finite-time runaway growth of droplet sizes due to larger droplets sweeping up smaller ones. The theory predicts that the period Δt to arrive at precipitation is related to the temperature sweep rate ξ by $\Delta t \sim \xi^{-3/7}$, in good agreement with the experiment. The theory also resolves an apparent bottleneck in the kinetics of rain droplet growth for warm clouds in a convectively stable atmosphere.

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A nonlinear dynamics approach to Bose-Einstein condensates

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It is well known that at sufficiently low temperatures the Gross-Pitaevskii equation (GPE), a nonlinear Schrödinger equation for the macroscopic wave function, provides an accurate description of the dynamics of dilute trapped Bose-Einstein condensates for both the ground state and the excitation spectrum. Because of its nonlinearity, the GPE can in general only be solved numerically, e.g. by imaginary time evolution. We pursue a different approach: We assume the wave function as a superposition of Gaussian wave packets, with time-dependent complex width parameters, insert it into the mean-field energy functional corresponding to the GPE, and apply the time-dependent variational principle. In this way the GPE is transformed into a system of coupled equations of motion for the complex width parameters, which can be analyzed with the methods of nonlinear dynamics, and which exhibits all the richness of phenomena typical of nonlinear systems, such as a transition from order to chaos or the appearance of different bifurcation scenarios. Even for condensates with long-range interactions (monopolar and dipolar), in addition to the short-range contact interaction, the method leads to highly accurate results for energies and wave functions, and thus turns out to be a full-fledged alternative to numerical quantum calculations. Moreover, the method is capable of giving access to regions of the space of solutions of the GPE that are difficult or impossible to investigate by conventional numerical calculations. A stability analysis of the fixed point solutions of the equations of motion even yields the low-lying quantum mechanical Bogoliubov excitation spectrum of the condensates.

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An Algorithm for Melnikov Functions and Applications

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In this work we study a dynamical system with a complicated nonlinearity, which describes oscillation of a turbine rotor, and give an algorithm to compute Melnikov functions for analysis of its chaotic behavior. We first derive the rotor model whose nonlinear term brings difficulties to investigating the distribution and qualitative properties of its equilibria. This nonlinear model provides a typical example of a system for which the homoclinic and heteroclinic orbits cannot be analytically determined. In order to apply Melnikov's method to make clear the underlying conditions for chaotic motion, we present a generic algorithm that provides a systematic procedure to compute Melnikov functions numerically. Substantial analysis is done so that the numerical approximation precision at each phase of the computation can be guaranteed. Using the algorithm developed in this paper, it is straightforward to obtain a sufficient condition for chaotic motion under damping and periodic external excitation, whenever the rotor parameters are given. This is a joint work with Jianxin Xu and Rui Yan.

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Abstracts of Short Reports

Geometric Correlations and Breakdown of Mesoscopic Universality in Spin Transport: From Spin Hall Effect to Topological Insulators

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In this talk I will discuss recent developments in semiclassical theory of spin transport. In particular, I will show how conventional theory of semiclassical transport is not able to describe spin transport phenomena in which charge currents generate pure spin currents or spin accumulations, namely spin Hall and Edelstein effects. I will then show how to construct a unified semiclassical theory of charge and spin transport in chaotic ballistic and disordered diffusive mesoscopic systems with spin-orbit interaction. Within the unified theory, the random matrix theory prediction that the spin conductance fluctuates universally around zero average, can be produced only by disregarding dynamic effects of spin-orbit interaction. However, these dynamic effects conspire together with geometric Hall correlations to generate finite average spin conductances, thus generating mesoscopic version of the spin Hall and Edelstein effects. The theory, which is confirmed by numerical transport calculations, allows the investigation of the entire range from the weak to the previously unexplored strong spin-orbit regime (i.e. the regime in which the spin rotation time is shorter than the momentum relaxation time). I will also discuss how these geometric correlations can be utilized to search for signs of Berry curvature of the underlying band structure in phase coherent transport. As an example I will focus on an n-doped 2d topological insulator mesoscopic structure, and show how geometric correlations can be utilized to obtain the Berry curvature from the weak spin-localization signal. Finally, I will discuss how spin currents generated with geometric Hall correlations interact with the topological insulator edge states thus generating observable signals in charge conductance.

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Transport properties of one-dimensional quantum chains –Lindblad approach, and C* algebraic approach –

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Despite recent developments of frameworks to study nonequilibrium systems, there is no consensus on which gives the appropriate way to deal with nonequilibrium states. Unfortunately, inconsistent results for the same systems due to different frameworks have been reported, and there is no consensus among them.
Therefore, it is of great importance to study simple systems, and to see the differences among the existing frameworks. As one of the simplest examples, we study a one dimensional fermionic chain. We mainly present the following two aspects.

1 Comparison among different methods.
We study transport properties of one dimensional periodic chains by using C* algebra and Lindblad equation. In the study of C*algebra, we study NESS (nonequilibrium steady state) of (1) infinite chain, and (2) finite chain coupled to infinite reservoirs at the edge of the chain.
For the system (2), we also discuss condition under which unique steady state exists.
In the study of Lindblad equation, we study a finite chain coupled to *infinite reservoirs* which are forced to different equilibria by a Lindblad operator. We use the technique of canonical quantization in the Fock space of operators, and discuss properties of NESS and relaxation to this NESS.

2 Transport properties of quasi-periodic and disordered chains
Using the Lindblad approach explained, we have studied quasi-periodic and disordered chains.

Microwave Measurements on Graphene-like Structures

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An experimental realization of finite tight binding graphene-like structures in a microwave setup is presented. The structures are realized using cylindric discs with a high index of refraction which are placed on a metallic surface. A second surface is adjusted atop the discs, such that the waves coupling the discs in the air are evanescent. In 2, 3 and 6 discs measurements we assured the validity ot the tight binding approximation. In reflection measurements performed in the centre of hexagonal lattices including 200 discs reminiscences of the Dirac point are observed, whereas resonances close to the Dirac points are found if the measurements are performed at the zigzag-edges or at the corner in case of a broken benzene ring.

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Velocity dynamics in conformally breathing billiards

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A point particle is moving freely inside a time varying domain while experiencing elastic reflections on its boundary. The energy is not conserved and can reach arbitrarily large value (Fermi acceleration). According to many numerical simulations in various billiard systems where Fermi acceleration is observed the mean velocity of an ensemble of particles follows the power law $\langle v \rangle = n^{\beta}$, where n is the number of collisions and β is the system dependent acceleration exponent. We shall present the first theoretical derivation [1] of $\beta = 1/6$ for important class of conformally breathing fully chaotic billiards. We shall also analyze the velocity dynamics of a single trajectory, independent of the properties of the underlying static billiard.

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DISOREDERED QUANTUM WIRE SWITCHING CAPABILITIES

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Development and miniaturization in the field of electronic components has achieved the stage, when devices make use of quantum coherent effects. Materials with anomalously high Fermi surface anisotropy are common in nanoscale. Transport characteristics of these systems are highly anisotropic, so while conductivity in chosen directions has typical metallic behavior, in localized dimensions we deal with jumps between layers, or even transport is denied. We give numerical analysis of controlling electric field effect on one-dimensional atom chain represented with a curve. Curve shape corresponds topology of several real systems; gaussian and angular shapes are used. In one-dimensional case we exploit Kronig-Penney model with atom potential disorder to calculate conductivity: time-independent Schrodinger equation is represented as recurrent equation [1]. Due to the absence of non-coherent scattering in the system we observe nonlinear field intensitiy. The dependence of transparencyversus field intensity can render a possible use in high-frequency switches. The second model represents a planar nanoscale curved channel of a finite width and previously defined shape with one electron passing through. We used Split-Step Fourier method. High amount of calculations required supercomputer usage. We compared results both model results. In every case transparency can be controlled by transverse field.

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Air Entrainment by Advancing Contact Lines

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The entrainment of air by a liquid jet plunging into a liquid reservoir has been studied in great detail. By contrast, the situation of a plunging solid, for which there is a moving contact line, is much less understood. We investigate this phenomenon experimentally by plunging a smooth solid plate into a reservoir of viscous silicone oil of different viscosities. When the plate speed is above a critical value, the surrounding air will be entrained to the liquid phase and form a thin air film. The air film is not stable but breaks up into small air bubbles quickly. We found that the critical speed for air entrainment depends on the oil viscosity in power law with scaling -1/3.

Semiclassics of Andreev Billards

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When coupling a superconductor to a normal conducting region the physical properties of the system are highly affected by the superconductor. One of the best known phenomena of such heterostructures is the induction of Cooper pairs into the normal region also known as the proximity effect. This proximity effect is also highlighted by Andreev reflection where an electron hitting the superconductor is retro-reflected as a hole and vice versa. The resulting behaviour enables one to decide whether the classical counterpart of the system is chaotic or not. While for integrable systems the density of states is suppressed exponentially for energies close to the Fermi energy, for chaotic systems a gap opens.

We combine a trajectory based semiclassical approach with Andreev reflection to show how subtle correlations between classical paths lead to a formation of the gap in the density of states for chaotic systems. We also include a phase difference between two superconductors and see how the phase difference reduces the effect of the superconductors due to the decoherence induced by the Andreev reflection. This approach can also be extended to the conductance and the thermopower of Andreev billards. We will see that the proximity of the superconductor leads to a quantum increase or decrease of the conductance of the same order as the classical conductance, depending on the size and the phase of the superconductor. Moreover we see how the correlations of the classical paths give rise to a finite antisymmetric thermopower showing that for Andreev billiards this is a purely quantum mechanical property.

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INTEGRABILITY CONDITIONS OF SOME COMPLEX SYSTEMS WITH HOMOGENEOUS NONLINEARITIES

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The problem of integrability of systems of differential equations is one of central problems in the theory of ODE's. Integrable systems are important in studying various mathematical models, since often perturbations of integrable systems exhibit rich picture of bifurcations.

Consider the center problem of system

$$\begin{aligned}\dot{x} &= x - a_{40}x^5 - a_{31}x^4y - a_{22}x^3y^2 - a_{13}x^2y^3 - a_{04}xy^4 - a_{-15}y^5,\\ \dot{y} &= -y + b_{5,-1}x^5 + b_{40}x^4y + b_{31}x^3y^2 + b_{22}x^2y^3 + b_{13}xy^4 + b_{04}y^5,\end{aligned} \tag{1}$$

where x, y, a_{ij}, b_{ji} are complex variables. It turns out the computations involved to the determination of the necessary conditions of integrability for the full family (2) are so heavy that they cannot be completed even using powerful computers and modern algebra systems. Thus, it is reasonable to study some subfamilies of system (2). Recently, the integrability conditions for the subfamily of (2), with $a_{-15} = b_{5,-1} = 0$, called Lotka-Volterra system, have been obtained in [1]. We study the integrability of system (2) with $a_{-15} = b_{5,-1} \neq 0$ and we found necessary conditions for existence of the local first integral for four subfamilies of this system. For the most cases we show that the obtained conditions are also sufficient conditions for existence of the local first integral.

We study also the integrability of the quartic system

$$\begin{aligned}\dot{x} &= x - a_{30}x^4 - a_{21}x^3y - a_{12}x^2y^2 - a_{03}xy^3 - a_{-1,4}y^4,\\ \dot{y} &= -y + b_{4,-1}x^4 + b_{30}x^3y + b_{21}x^2y^2 + b_{12}xy^3 + b_{03}y^4.\end{aligned} \tag{2}$$

For the particular subfamily of (2), where $a_{-1,4} = b_{4,-1} = 0$, we first find necessary conditions for integrability. Then we construct first integrals of the corresponding systems or at least show, that under the obtained conditions such integrals exist.

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STATISTICAL PROPERTIES OF TIME-DEPENDENT SYSTEMS

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We study some dynamical properties of time dependent systems. It is well known that the structure of the phase space depends on the individual characteristics of each system. Here, we consider the two types, namely, one integrable (elliptical billiard [1,2]) and one mixed (Standard map [3]). Our main goal is to understand and describe the behaviour of the particle's average velocity (and hence its energy) as a function of the number of collisions considering both, the conservative as well as the dissipative dynamics. For the dissipative case we consider two kinds of dissipation, namely, collisional dissipation and in-flight dissipation. Our results confirm that unlimited energy growth is observed for the non-dissipative case in the three cases. However, when dissipation is introduced via inelastic collisions or in-flight dissipation, the scenario changes and the unlimited energy growth is suppressed, thus leading to a phase transition from unlimited to limited energy growth. The behaviour of the average velocity is described using scaling arguments. Finally, we propose a new universal empirical function to describe this scaling behavior with only one parameter left, namely the acceleration exponent.

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Probing decoherence through Fano resonances

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We investigate the effect of decoherence on Fano resonances in wave transmission through resonant scattering structures. We show that the Fano asymmetry parameter q follows, as a function of the strength of decoherence, trajectories in the complex plane that reveal detailed information on the underlying decoherence process. Dissipation and unitary dephasing give rise to manifestly different trajectories. Our predictions are successfully tested against microwave experiments using metal cavities with different absorption coefficients and against previously published data on the temperature dependence of transport through quantum dots.

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DELOCALIZATION IN A NONLINEAR GENERALIZATION OF THE QUANTUM KICKED ROTOR

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One of the most interesting effects discovered in the domain of quantum chaos is the quantum suppression of classical chaotic diffusion. It was first observed numerically in the quantum kicked rotor model. This phenomenon in many aspects can be considered as the dynamical version of Anderson localization in the tight-binding disordered models. However, in the case of quantum chaos there is no randomness and transient diffusion in the corresponding classical system. Namely, the dynamical localization in a quantum kicked rotor occurs in a completely deterministic system. The realization of the Bose-Einstein condensates in dilute gases has opened a new opportunity for investigating dynamics of the many-body systems in the presence of interactions between their constituents. In the mean field approximation, the interactions can be modeled by adding a cubic nonlinear term in the corresponding Schrödinger equation. This approach can be extended to the quantum kicked rotor model resulting in its nonlinear generalization. Our aim is to utilize such model, which was introduced by Shepelyansky, in order to understand how the nonlinearity generally affects the kicked rotor model. Particularly, we aim to understand the influence of nonlinearity on dynamical localization. The special concerns are to identify a critical nonlinear strength above which localization is destroyed, and mechanism of the localization destruction. Finally, we consider the corresponding anomalous subdiffusion law in the destruction regime, compare it with the subdiffusion laws derived in other nonlinear system with disorder, and test its universality.

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Non-equilibrium phase transition in a periodically driven XY spin chain

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We present a general formulation of Floquet states of periodically time-dependent open Markovian quasi-free fermionic many-body systems in terms of a discrete Lyapunov equation. Illustrating the technique, we analyze periodically kicekd XY spin 1/2 chain which is coupled to a pair of Lindblad reservoirs at its ends. A complex phase diagram is reported with re-entrant phases of long range and exponentially decaying spin-spin correlations as some of the systems parameters are varied. The structure of phase diagram is reproduced in terms of counting non-trivial stationary points of Floquet quasi-particle dispersion relation.

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Covariant Lyapunov Analysis of Chaotic Kolmogorov Flows and Time-correlation Functions

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We study a hyperbolic/non-hyperbolic transition of the flows on two-dimensional torus governed by the incompressible Navier-Stokes equation (Kolmogorov flows) using the method of covariant Lyapunov analysis developed by Ginelli et al.(2007). As the Reynolds number is increased, chaotic Kolmogorov flows become non-hyperbolic at a certain Reynolds number, where some new physical property is expected to appear in the long-time statistics of the fluid motion. Here we focus our attention on behaviors of the time-correlation function of vorticity across the transition point, and find that the long-time asymptotic form of the correlation function changes at the Reynolds number close to that of the hyperbolic/non-hyperbolic transition, which suggests that the time-correlation function reflects the transition to non-hyperbolicity.

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Manifold structures of unstable periodic orbits and the appearance of periodic windows in chaotic dynamical systems

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It is known that properties of chaos can be characterized in terms of unstable periodic orbits. In this presentation, manifold structures of the Lorenz system and the Kuramoto-Sivashinsky system are investigated in terms of unstable periodic orbits embedded in the attractor. Especially, the change of manifold structures are focused on when some parameter values are varied.

It is found that the angle between a stable manifold and an unstable manifold (manifold angle) at sample points on an unstable periodic orbit, which is measured by using the covariant Lyapunov vectors, characterizes the parameter at which the periodic window corresponding to the unstable periodic orbit finishes, that is a saddle-node bifurcation point. In particular, when the minimum value of the manifold angle along an unstable periodic orbit is small (large), the corresponding periodic window exists near (away from) the parameter. It is concluded that the window sequence in a parameter space can be predicted from the manifold angles of unstable periodic orbits at some parameter. This approach helps us find periodic windows including quite small ones.

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TIME-SPACE DISTRIBUTED MODEL OF DYNAMIC AND POWER CHARACTERISTICS SOLID STATE LASERS

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Solid-state lasers with diode pump are very attractive because of their compactness, high output, high efficiency. The configurations of such lasers are rather different. Geometrical and power parameters optimization issues for this laser type remain actual. However, problems of optimization are being solved still only in the case of steady-state regime. This excludes important issues from consideration such as lasing formation process.In our paper [1], we introduced semi-classical model of one-dimensional distributed laser system. This model makes possible to describe evolution of spatially-distributed laser generation for Er-Yb laser with longitudinal and transversal diode pumping. We generalized model [1] for solid lasers, particularly, for the laser with neodim ions. We did numeric simulation of fiber lasers and short lasers. Optimization characteristics for threshold and pump, slope and geometric parameters of active medium were obtained. Also, evolution of the system was investigated, transitional characteristics were reconsidered via spatially-distributed model. We demonstrated, that optimization is possible not only for fiber lasers, but also for short lasers.

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Newtonian and special-relativistic probability densities for a low-speed system

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The Newtonian and special-relativistic predictions for the position and momentum probability densities of a model low-speed (i.e., much less than the speed of light) dynamical system are compared. The Newtonian and special-relativistic probability densities, which are initially the same Gaussian, are calculated using an ensemble of trajectories. Contrary to expectation, we show that the predictions of the two theories can rapidly disagree completely. This surprising result raises an important fundamental question: which prediction is empirically correct?

Periodic orbits and transport in mixed phase spaces

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Though the transport properties of chaotic systems are computable from periodic orbits, in practice, such computations are easiest to realize in sufficiently hyperbolic systems dominated by short orbits. Phase spaces exhibiting a mixture of chaos and regularity, however, present a greater challenge, owing to the richer topological dynamics in the vicinity of stable islands and the importance of longer orbits. We demonstrate how, using a sufficiently accurate symbolic dynamics, periodic orbit techniques can compute classical decay rates even in a strongly mixed phase space.

SYMMETRY REDUCTIONS OF A FAMILY OF TIME-DEPENDENT ANHARMONIC OSCILLATORS

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Some group theoretic methods for integrating differential equations due to S. Lie and E. Noether are introduced and then applied to a class of time-dependent nonlinear second order differential equations.

In particular, in the first part of this talk some basic concepts will be briefly introduced; namely: continuous groups of transformations and their infinitesimal generators, the concept of a symmetry of a differential equation, simple methods of finding those symmetries (using Lie's algorithm) and how to use them (how to reduce the order of the equation by one, or two in the case of Noether symmetries for equations derived from a variational principle) [1,2,3].

In the second part, Lie's method will be applied to a class of time-dependent, nonlinear oscillators with cubic nonlinearity [4]. A classification of different cases with respect to their Lie point symmetries will be presented and the corresponding reductions of the order of each equation will be given. In some of these cases a second reduction, i.e. integration, is possible due to the special character of the symmetry, namely to preserve also the action integral (that is to be of Noether type). In such cases explicit exact analytic solutions of the underlying systems are given.

This analysis was motivated by the studies of the adiabatic invariants and of the statistical properties of time dependent Hamiltonian systems, the linear and nonlinear oscillators, and finds application in this context, see [5,6] and references there in.

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How horseshoes are destroyed and what comes afterwards

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We investigate the dynamics of strongly dissipative Henon maps at the first bifurcation parameter at which the uniform hyperbolicity is destroyed by the formation of tangencies inside the limit set. In a parameter interval of transition from horseshoes to chaotic attractors, we prove that the relative frequency of chaotic transient tends to one as the Jacobian tends to zero. We also present numerical results which support the conjecture of Grebogi, Kan, Lai & Yorke on the frequency of non-hyperbolic chaotic transient.

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HEAT TRANSPORT IN QUANTUM HARMONIC CHAINS WITH REDFIELD BATHS

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Numerical or analytical investigation of open many-body quantum systems is a demanding task due to the exponential increase of the dimension of the Hilbert space. Consequently, there is a lack of explicit analytical results, which exist mainly for small systems, despite the fact that many simple cases of the effective Redfield and Lindblad master equations have been studied. The Redfield and the Lindblad master equations for general quadratic fermionic or bosonic systems can be solved explicitly by using canonical quantization in the Fock space of operators - third quantization for short. This method was used to find and explain the novel, non-equilibrium quantum phase transition in the one-dimensional XY spin 1/2 chain and to calculate some explicit analytic results for the transport coefficients in the harmonic oscillator chain and the XXZ model.

We will consider the third quantization for bosons on the example of the harmonic oscillator chain and derive some explicit results for the thermal conductance. Possible extensions and applications of the method to interacting models will be discussed.

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Abstracts of Posters

HURST PARAMETER IN PATTERN OF LASER HARDENED TOOL STEEL

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A rough surface can be observed in the microstructure of the robotically laser hardened material. We are interested in how to assess the roughness. The Hurst parameter is directly related to the "fractal dimension", which provides the measure of surface roughness. The Hurst parameter is understood as the correlation of two random steps X1 and X2 which follow one another with the time difference t. We analyzed 36 samples of the same hardness with different parameters of a robotic cell for laser hardening with the R/S method. The main findings can be summarized as follows: We observed a fractal structure in robotic laser hardening. By applying different calculation methods, we gauged the Hurst parameter H for various parameters of laser hardening of robotic cells. We found the most optimal Hurst parameter H for different parameters of robotically laser hardened tool steel. Using the RGB analysis we got three-dimensional graphs, which show a fractal structure. Because of the occurrence of self-similar deformations due to heat treatment in robotic laser hardening, the fractal dimension can be used to describe the level of irregularity.

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FRACTAL STRUCTURE OF ROBOT LASER HARDENED DIFFERENT MATERIAL

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Laser hardening is a metal surface treatment process complementary to conventional flame and induction hardening processes. A high-power laser beam is used to heat a metal surface rapidly and selectively to produce hardened case depths of up to 1,5mm with the hardness of the martensitic micro-structure providing improved properties such as wear resistance and increased strength. Fractal patterns are observed in computational mechanics of elastic-plastic transitions. The Fractal dimension is a property of the fractal, which is maintained through all the extensions and is therefore well defined. In addition, it shows how complex the fractal is. The Fractal dimension is generally not calculated by the above-mentioned procedure, as this is possible only on pure mathematical constructs, which do not exist in nature. We made samples on material GGG 70L and GGG 60L, where we observed a fractal pattern in the microstructure of the robotically laser hardened material.

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Time series analysis of turbulent systems

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Time series analysis has been widely used to determine the properties of turbulent systems in separate cases, in particular chaotic turbulence (Eckmann and Ruelle, 1985) and stochastic turbulence (Moss and McClintock, 1989). However, they are rarely analysed together or with the same methods. In addition, the application of time series analysis to turbulence from the emerging class of nonautonomous systems (Rasmussen and Kloeden, 2011) has yet to be fully considered.

The effectiveness of different time series methods is highly dependent on the source of the turbulence. This work emphasises the importance of using a wide range of techniques, especially in the case where turbulence is observed but the origin is unknown. The proper treatment of time series containing time-dependent dynamics (Jamšek, Paluš and Stefanovska, 2010) is also investigated.

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Semiclassical Propagator for Bosonic Quantum Fields based on Real Trajectories

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A powerful alternative to describe an interacting many-body quantum system is to study the quantum field theory of the asociated wave equation. In this approach, the path integral over configurations of the classical field is naturally constructed in the many-body eigenstates of the field operators, the so-called field coherent states, and the semiclassical program can be in principle carried on following a saddle point calculation of such path-integral representation. However, already at the single-particle level, the experience of the past decades shows the absolute necessity of including complex classical trajectories to get a consistent semiclassical theory based on the coherent sate representation. The complicated issues of analytical continuation, existence of well-behaved solutions and practical calculation of classical complex trajectories makes then the coherent state approach useless (as far as real-time propagation in the semiclassical limit is concerned) when going into interacting fields.

A possible solution for all this problems would be to start the semiclassical program with the strict analog for quantum fields of the Van-Vleck propagator, as from the begining this object is constructed out of real classical trajectories.

Using field states which are closely related with coherent states and may be seen as the formal analogue of position and momentum operators in the phase space where the classical field evolves, we show that a Van-Vleck propagator may be constructed out of real trajectories in field space. We discuss the formal properties of this object and apply the corresponding semiclassical theory for interacting bosons to some simple models.

FERMI ACCELERATION AND ITS SUPPRESSION IN A TIME-DEPENDENT LORENTZ GAS

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In our work, we revisit the problem of a Lorentz Gas [1] with time-dependent boundary. We assume that the radius of the scatters are fixed and the center of mass changes according to an harmonic function. Our main goal is, for the conservative case, to verify the validity of the Loskutov-Ryabov-Akinshin (LRA) conjecture [2] which states that: Chaotic dynamics of a billiard with a fixed boundary is a sufficient condition for the Fermi acceleration in the system when a boundary perturbation is introduced. It was confirmed when we studied the behaviour of the average velocity for an ensemble of particles. Since the phenomenon of Fermi Acceleration is present in this model our next step is to introduce dissipation into the model via damping coefficients. For dissipative billiards, Leonel proposed the following conjecture [3]: For one-dimensional billiard problems that show unlimited energy growth for both their deterministic and stochastic dynamics, the introduction of inelastic collision in the boundaries is a sufficient condition to break down the phenomenon of Fermi acceleration. In our approach, we are studying a two-dimensional system close to the transition from unlimited to limited energy growth. Our results allow us to confirm Leonel's conjecture for this new kind of time-dependent perturbation when dissipation is introduced. In both, conservative as well as dissipative case, we describe the behaviour of average velocity using scaling formalism [4,5].

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Time series analysis of molecular dynamics simulation: collective behavior and configuration changes

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Our study aims to analyze time series data of dynamics simulation for proteins to extract collective behavior which plays an important role in molecular functions. In a traditional idea of proteins, the most stable configuration is supposed to play an important role in their functions. In a stable configuration, the protein has hierarchical structures: the primary, the secondary and the tertiary ones. The primary structure of the protein is the chain of amino acids. The secondary structure of the protein is formed after folding processes, and consists of helix, sheets and loops. Its tertiary structure is constituted by these secondary structures.

However, recent studies suggest that some proteins exhibit dynamical changes of their structures and such dynamical behavior plays a crucial role in their functions. Our interest in dynamical behavior of proteins is stimulated by these recent studies. In particular, we focus our attention to collective behavior of proteins and seek to understand how such behavior is related to molecular functions.

Our system is chignolin, the first designed protein consisting of 10 amino residues. Up until now, 18 stable structures are found for chignolin. Moreover, the protein exhibits dynamical behavior where it wonders around several stable configuration. Thus, it is a convenient molecule to develop methods to analyze dynamical motions taking place around multiple configurations.

We analyze how the protein experience multiple stable configurations by calculating the Root Mean Square Deviation (RMSD). Our analysis reveals that some structures appear more often than the other structures. In addition, using wavelet transformation and singular value decomposition, we classify vibrational motions. We discuss possible relationship between collective motion revealed by these analysis and dynamical changes among multiple stable configurations.

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Diffusion in a Quasiperiodic Lorentz gas.

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The Lorentz Gas (LG) is a kind of open billiard where the obstacles are hard disks. Diffusion in these systems is an interesting topic of study and is related to the glassy state of hard disks in binary systems. In a periodic LG normal diffussion and super-diffusion have been found, while in random systems sub-diffusion occurs.

We are interested in an intermediate case, that of quasiperiodic systems. It is, however, much harder to make a computational study in this case, since it is not possible to use periodic boundary conditions.

This poster will present some results on diffusion in the quasiperiodic LGand a new method for studying such systems numerically.

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ANDERSON LOCALIZATION BREAKUP IN STRONGLY DISORDERED NONLINEAR LATTICES

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The general wave phenomenon of Anderson localization - the halt of wave-packets in linear disordered media - affects a variety of classical or quantum waves. In turn, it impacts electrical and thermal conductivities, promotes localization of light and matter waves in optical lattices. Nonlinearity can strongly alter Anderson localization and the question whether the Anderson localization survives the nonlinearity or not is under a hot debate in nonlinear science and condensed matter. We report that employing the perturbation theory techniques one can demonstrate a finite probability for an Anderson mode (a regular compact localized solution) of a finite energy to be destroyed by nonlinearity, whatever small it is, and, hence, a finite probability of spreading.

Numerical experiments confirm theoretical predictions and demonstrate a sensitive dependence of the wave-packet dynamics (spreading or non-spreading) on the disorder realization in case of small energies. They reveal a linear dependence of the non-spreading probability on the wave-packet energy. For higher energies the non-spreading probability asymptotically vanishes and, in numerics, all realizations of disorder supported spreading. Although the spreading process may be quite irregular and get slower with the decrease of the total energy, no sign of slowing down in course of wave-packet spreading as the energy density decays has been documented.

Invariant manifolds in chaotic advection-reaction-diffusion pattern formation

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Invariant manifolds are organizing structures central to the problem of transport in chaotic advection, having been applied extensively in periodically driven systems and more recently extended, in the form of Lagrangian coherent structures, to fluids that are not strictly time-periodic. Here, we consider reaction-diffusion dynamics in systems that are simultaneously undergoing chaotic advection. This can be viewed as a simplified model of such diverse systems as combustion dynamics in a chaotic flow, microfluidic chemical reactors, and blooms of phytoplankton and algae. Prior experimental and numerical work has shown that such systems generate "burning fronts" with a remarkably rich structure, including the mode locking of the front profile to the driving frequency. Here, we demonstrate how the invariant manifolds useful in chaotic advection can be generalized to accommodate the additional reaction-diffusion dynamics. The generalized manifolds exist in an extended phase space that is of larger dimension than the fluid itself. We show how these manifolds provide a clear criterion for the existence of mode-locking and are essential for explaining the patterns of the mode-locked fronts. Finally, we present recent experimental results on the direct laboratory measurement of such manifolds.

NUMERICAL STUDY OF SOME NONAUTONOMOUS NONLINEAR OSCILLATORS

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We consider some nonlinear (anharmonic) nonautonomous Hamiltonian oscillators of one degree of freedom, that change adiabatically in time, thereby generalizing the theory on the time dependent linear oscillator [2,6-10]. For these systems we make a numerical study using several symplectic integrators. Comparison of numerical approximations with analytical solutions is given. The (non)conservation of the adiabatic invariant, namely of the action J, is studied. For the long-term integration we have chosen the 8th order symplectic integrator due to McLachlan [4] (for more informations see also the review paper of McLachlan and Quispel [5]) and investigated some statistical properties of the nonautonomous systems adiabatically changing in time. A short review of the methods used will be given [1,3,10-13].

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Low-dimensional dynamics of large ensembles of globally-coupled non-autonomous phase oscillators

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The Kuramoto model (KM) is used today as general approach in tackling non-linear problems that can be reduced to large ensembles of coupled phase oscillators (Acebrón et al. 2005). We extend it to incorporate at a basic level one of the most fundamental properties of living systems - their inherent time-variability. This enables a wide field of real problems to be addressed, where the observed system's dynamics is influenced by some external field so that some of its inherent parameters become non-autonomous (NA).

Recent results by Ott and Antonsen demonstrate that systems of globally-coupled non-identical phase oscillators have low-dimensional dynamics (Ott and Antonsen 2008). We use their ansatz to derive an explicit finite set of nonlinear ordinary differential equations, to describe the macroscopic evolution of our NA system. Furthermore, we show that the classical approach to this problem, using self-consistency of the mean field, fails to unveil the real behavior of the system - where the dynamics of the external field is superimposed on the top of the original problem defined by the KM.

The differential equations describing the low-dimensional dynamics of the different NA KM, are linearized around fixed points $z = 0$. This allows the critical parameters at which perturbations become unstable to be tracked, as well as, the damping rates for stable perturbations. Since, this is a typical example of a system with NA dynamics, characterized by explicit time dependance of the fixed points and bifurcation parameters (Rasmussen 2007), further analysis of the attractors' stability, given by the dynamics of the complex order parameter evolution and its linearization will be of great importance for the general theory of NA systems.

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SYNCHRONIZATION OF INTERACTING OSCILLATORS SUBJECT TO EXTERNAL NON-AUTONOMOUS INFLUENCES

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Time-variability is almost universally present in the dynamics of interacting oscillators in nature. Thus in biological oscillators it is common for parameters such as the natural frequencies to vary in time, the human cardiovascular system providing a well-known example (Shiogai et al. 2010). This time-variability may arise due to intrinsic variations in a high-order system, or multi-stability, or can be due to external influences. The latter situation is most probable when the oscillatory systems are thermodynamically open and other (often oscillatory) processes coexist in the same environment. We consider the case of oscillators that are self-sustained when in isolation (Anishchenko et al. 2010), and which are subject to external influences that may be periodic, stochastic or chaotic. Where two or more oscillators mutually interact, synchronization may occur (Pikovsky et al. 2001), and one of our central purposes is to reveal and understand the synchronization of self-sustained oscillators while influenced by non-autonomous sources. Analytic and numerical methods are introduced to take explicit account of the non-autonomicity, and applied to describe synchronization between coupled Poincaré oscillators subject to non-autonomous fields that tend to influence the frequencies or amplitudes, and/or the strength of the inter-oscillator coupling (Stankovski et al.). In each case the stability of the synchronization is considered, together with that of the associated phase difference, which is now dynamically varying. Bifurcation diagrams are constructed to distinguish parameter ranges of synchronization, partial synchronization, and non-synchronization. Finally, we discuss a method (Duggento et al.) for the detection of synchronization, and characterisation of the underlying phase dynamics, through analysis of the time series generated by non-autonomous oscillators.

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Prevalent dynamics at the first bifurcation of the Henon map

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We study the dynamics of strongly dissipative Henon maps, around the first bifurcation parameter a* at which the uniform hyperbolicity is destroyed by the formation of tangencies inside the limit set. We prove that a* is a full Lebesgue density point of the set of parameters for which Lebesgue almost every initial point diverges to infinity under positive iteration. A key ingredient is that a* corresponds to "non-recurrence of every critical point", reminiscent of Misiurewicz parameters in one-dimensional dynamics. Adapting on the one hand Benedicks & Carleson's parameter exclusion argument, we construct a set of "good parameters" having a* as a full density point. Adapting Benedicks & Viana's volume control argument on the other, we analyze Lebesgue typical dynamics corresponding to these good parameters.

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Takahasi H 2011 *Arxiv* http://arxiv.org/abs/1011.4200

Concerts

CONCERT

STRING QUARTET FEGUŠ

Kavarna Art, Hotel PIRAMIDA

Tuesday, 28 June 2011, 21:00

Program

J. Haydn: Godalni kvartet v G-duru op.77, št.1, Hoboken III:81

Allegro moderato

Adagio

Menuet.Presto

Finale.Presto

"Brothers Feguš have obtained their place under the sun with high level of their art by which they insist. Their performance is distinguised by high level of focus, rounded sound, related experiencing of musical arts, important talent and knowledge worth of consideration. We cannot ignore the fact, that they perform before concerts halls full with audience, which nowdays rises so much greater attention." (J. Šetinc, 11.11.2009, Večer).

FEGUŠ STRING QUARTET has been performing since 1992, it's members are brothers: Filip and Simon Peter violin, Andrej viola and Jernej cello. They started their educational path at Maribor Music Conservatory, after which their studirs continued at State Conservatory of Carinthia in Klagenfurt (Austria). In year 2001, Feguš String Quartet has been accepted for study of chamber music at prestigious private school *Scuola di Musica di Fiesole* (Florence, Italy) under mentorship of Milan Škampa (Smetana Quartet) and Piero Farulli (Quartetto Italiano), as well as Andreo Nannoni (Nuovo Quartetto) until year 2007. For their study they have also received stipendum of Italian President Carlo Azeglio Ciampi. Since year 2008 they are enrolled in master studium of chamber music at Universitt fr Musik und darstellende Kunst Graz by Stephan Goerner (Carmina Quartet). *"Quartet Feguš is different from other already heard instrumental groups, that have the same composition, and as such is becoming comparable with topmost of string quartets"* (M. Šijanec, 17.11.2005, Večer).

They have upgrated their knowledge on numerous international master classes, held by members of world known quartets: Alban Berg Quartet, Amadeus Quartet, Borodin Quartet, Emerson Quartet, Juilliard Quartet, LaSalle Quartet, Guarneri Quartet as well as others. In year 2001 Feguš String Quartet has qualified for *Isaac Stern Chamber Music Workshop* in Carnegie Hall (New York) under leadership of legendary violinist Isaac Stern and members of the best American Quartets. They have participated on Orlando Festival, Kerkrade in Netherlands, Festival Pablo Casals in Prades, France, Festival *Strings Only!* in Zadar, International Festival of Young Musicians *DAM* in Priština and others. They have concerted throughout Slovenia, Europe and USA (Pariz, Berlin, London, Washington, New York, Florence, Vienna itd.) They recorded for Radio Slovenia, Radio Maribor, ARD, ORF, France Musique. World premieres have been given of the Slovene and foreign composers: P. Ramovš, A. Lajovic, M. Feguš, J. Golob, D. Močnik, A. Weingerl, Č.S. Voglar, K. Alikaj, K. Gashi, D. Zeqiri, S. Spadini. In year 2006 they released cd-disk with works of L. Janček and M. Ravel. Also their hometown has given them special recognition for their work: they received City Seal of Maribor and Glazer's Charter for accomplishments in the area of culture. In Piran they also receieved an award for the best performance of Tartini work.

CONCERT

Urška Orešič

Kavarna Art, Hotel PIRAMIDA

Saturday, 2 July 2011, 20:00

Program

1. FLY ME TO THE MOON (B. Howard)
2. DEMONI* (F. Lainšček & U.Orešič)*
3. SPLEEN* (F. Lainšček & U. Orešič)*
4. I'VE GOT YOU UNDER MY SKIN (C. Porter)
5. OVER THE RAINBOW (H. Arlen)
6. SAVING ALL MY LOVE FOR YOU (M. Masser & G. Goffin)
7. FOR ONCE IN MY LIFE (R. Miller & O. Murden)
8. YOU'VE CHANGED (C. Fisher)
9. AFRODITA (F. Lainšček & U. Orešič)*
10. SPOSODIM SI (STAR BICIKLIN)(F. Lainšček & U. Orešič)*
11. ALL OR NOTHING AT ALL (J. Lawrence & A. Altman)
12. NINE MILLION BICYCLES (M. Batt)
13. BESAME MUCHO (C. Velzquez)

* First performance

Urška Orešič (1981) began with first musical education in her home town Maribor. While taking her first years of piano lessons at the primary Music School she began to compose her own musical ideas by improvising on the piano. She continued with studying the piano and theory at Musical High School. She trained her voice in a world famous youth choir Carmina Slovenica and continued with solo-singing in Ljubljana. In 2001 she accepted to Music Academy in Ljubljana where she was studying the composition and music theory with mentor Prof. Pavel Mihelčič and later the piano with mentor prof. Andrej Jarc. She successfully graduated in composition in 2005 with writing one act Opera An Evening with Rafael. She took parts at different seminars and Summer schools of composition in Europe and worked with professors F. Burt, L. Voigtlaender and G. Fekete. Later she graduated in piano studying with mentor Prof in June 2009. Now she is finishing her Masters degree (magisterial) of composition at Music Academy in Ljubljana. Her musical opus includes different works for solo, choir, chamber and orchestral ensembles, although she prefers to work on vocal and piano-vocal music. The important pieces are: The Sketches for strings (performed by Chamber Slovene Filharmonic Orchestr and Camerata Labacenzis), Triton (recorded for Slovene promoting music with Radio Philharmonic orchestra and conductor En Shao), Flinstone from the Sun (written and performed by Slovenian Octet)... Urška Orešič was a member of Zois scholarship and a student's Preseren Prize. As academic musician and the professor of musical art of theory and piano she is working as a composer, chamber musician, pianist and singer of different musical styles. She is employed as a piano teacher and piano accompanist at Gornja Radgona Music School and a member of Big Band Music school of Gornja Radgona & Radgonske Gorice. In past few years she has also been working as a hotel pianist and singer in Rogaška Slatina.

CONCERT

TRIO INFINITUM

Simon Petek - violin **Ana Kopše** - violoncello **Nejc Kamplet** - piano

Kazinska Dvorana, SNG Maribor

Tuesday, 5 July 2011, 21:00

Program

Joseph HAYDN: Piano trio no. 39 in G major Hob. XV/25

Andante
Poco Adagio, cantabile
Rondo al'Ongarese: Presto

Dmitri SHOSTAKOVICH: Trio no. 2 in E minor,

Largo

Antonin DVORAK: Piano trio in E minor, Op. 90, *Dumky*,

Lento maestoso
Poco Adagio
Andante
Andante moderato
Allegro
Lento maestoso

The piano trio INFINITUM was founded in 2009 and consists of Simon Petek violin, born 20.6.1992, Ana Kopše cello, born 16.9.1992 and Nejc Kamplet piano, born on 7.9.1996. They work under the mentorship of prof. Petra Neuvirt. Beside the love for music the group members are linked by the fact, that they all come from musical families, they all are excellent young soloists, who also perform independently and have already proven themselves at musical competitions; all of them are winners of gold medals and first prizes both at home and abroad. They are all students at the Conservatory for music and ballet in Maribor and upgrade their knowledge with renowned teachers both as soloists and as chamber musicians. They excel with fresh, colourful and harmonious playing, with which in March 2011 they won the gold medal and 1. Prize at the 40. Temsig competition for young Slovenian musicians in the category under 19 years.

CONCERT

Duo Fla-Via

Kavarna Art, Hotel PIRAMIDA

Wednesday, 6 July 2011, 20:00

Program

C. Ph. E. Bach: Duet for flute and violin
Andante
Allegro
Allegretto

G. Cambini Duet for flute and violin op. 14
Allegro
Andantino

J. S. Bach: Praeludium and Gavotte from Partite No. 3 for solo violin, BWV 1006

L. Van Beethoven: Allegro and Minuet
Allegro con brio
Minuetto quasi allegretto

S. Karg-Elert: Sonata Appassionata in f# major for solo flute

A. Rolla: Duet for flute and violin
Andante sostenuto
Rondo alla Polacca

W. A. Mozart: Movements from the opera Marriage of Figaro

Duo Fla-Via are Špela Kržan (flute) and Barbara Danko (violin), two young and talented musician, who despite their youth already have a varied and rich musical past. Both of them gathered their musical knowledge abroad (Vienna, Austin, Saint Petersburg, Paris) and are professionaly active in Slovenia, as well as abroad. They formed the Duo Fla-Via in December 2009. Since then Duo Fla-Via has had some very successful concerts. Among the most popular were concerts at Ptuj and in Litija.. They repertoire is broad and consists of chamber works for flute and violin and soloistic pieces for both instruments. One of their strengths as musicians is also the ability to present classical music in an unclassical wayy and they also play different styles (Folk music, Latin music, Tango, Rock music...). Because of that Duo Fla-Via is an interesting, fresh and versatile chamber ensemble.

Mag. art. Špela Kržan (flute) completed her postgraduate studies of flute with honours at the University of Music and Dramatic Arts in Vienna, where she studied with professor Hansgeorg Schmeiser-ROM. She studied at the "Conservatoire National Superieur de Musique et de Danse de Paris" with professors Vincent Lucas, Sophie Cherrier, and Philippe Bernoldi as a part of international exchange of students - Erazmus, In September 2009 she won the international competition for the flute in Israel - Haifa International Flute Competition 2009. She also successfully participated in other international competitions, including the ARD Competition in Munich, Jeunesse Musicales in Romania, Bhm Competition in Munich, Domenico Cimarosa, Italy She attended several masterclasses with renowned professors like Luisa Sello, Aurelle Nicolet, Davide Formisano, Jan Ostry, Karl Heinz Schtz, Natalie Rozat, Aleš Kacjan, Gaspar Hoyos in drugi. Špela Kržan continues her solo career as a concert flutist and a member of chamber ensembles with harp, organ and violin at home and abroad. She was a long-standing member of Youth Symphony Orchestra, Wiener Jeunesse Orchester, with which she attended an orchestral tour in Bombay (India) in February 2008. Occasionally she participates in the Vienna People's Opera, Vienna Volksoper. In August 2009 she held a masterclass for flute in Radlje ob Dravi. She is currently employed as a professor of flute at SGBŠ Maribor, Lenart, at a private music school in Gornja Radgona Maestro and Music School in Radlje ob Dravi. She is a co-founder of Duo Fla.-Via.

Barbara Danko, M. M. (violin) started her musical path at the age of six with the professor Zvonka Pal at the Elementary school of music in Maribor. Her talent was soon revealed and she won a second prize at the International violin competition Alpe-Adria at the age of eight.. She continued her musical training at the High school of Music and Ballet in Maribor with Ivan Pal.. At the age of sixteen she was admitted to the Academy of Music in Ljubljana as highly talented to study with professor Rok Klopčič. In 2006 she was accepted to a postgraduate program at The University of Texas at Austin, Austin, Texas, for which she also received a University grant. There she studied with Dr. Eugene Gratovich. She completed her studies with honors in May 2008. Barbara competed in several national and international competitions and achieved high rankings She attended music festivals in Europe (Saint Petersburg, Russia; Burgos, Spain; Viana do Castelo, Portugal) and the USA (Austin, Texas), where she also had solo recitals. In 2008 she was honored by the University of Texas at Austin for an outstanding masters recital. She was one of the first members of Austin Pops, the leading Austin orchestra for popular music and regularly worked with Temple Symphony Orchestra and Brazos Valley Symphony Orchestra. During her time at the UT at Austin she was also a member of String Project, an organization for educating children in string instruments. She was also Dr. Eugene Gratovichs teaching assistant. She is currently employed as violin teacher at the Private music school in the monastery of Saint Peter and Paul in Ptuj and the Private music school Maestro in Gornja Radgona. She is also active as a solo and chamber musician and is a member of a rock group Avven. In the summer of 2009 she organized the festival Glasba v Kloštru, which had a great response. She is a co-founder of Duo Fla-Via and is a member of string quartet InQuartet.

CAMTP

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