CAMTP

”Let’s Face Chaos through Nonlinear Dynamics”

9th International Summer School/Conference

University of Maribor

at the University of Maribor
22 June - 6 July 2014

Dedicated to the 65th Birthday of Professor Theo Geisel

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, once every three years. This year we have 38 invited lecturers, most of them are leaders in this sphere of science, and 27 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 already 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, engineering and even economics 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.

We are proud to emphasize that this Summer School and Conference is for the first time under the patronage of the European Academy of Sciences and Arts, and on this occasion the Academy will be represented by Professor Dr. Branko Stanovnik, who is the Dean of the Class of Natural Sciences.

I should like also to emphasize the personal component of the 9th School/Conference, namely the fact that it is dedicated to the 65th birthday of Professor Theo Geisel (born on 24 August 1948), from Max-Planck-Institute for Dynamics and Self-Organization and University of Göttingen, Germany. It is on Tuesday 1 July 2014 at 19:00 that we shall start the official celebration of his 65th birthday, beginning with a concert by Urška Orešič, followed by the speeches and laudatio, followed by the banquet. For more details about his scientific opus please see the next section.

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, 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, the University of Maribor represented by the Rector Professor Danijel Rebolj, the City of Maribor, represented by the Mayor of the Town, Dr. Andrej Fištravec, GEN Energija, Energija Plus and MAGNA STEYR.

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 2014, 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, 16 May 2014

Professor Theo Geisel

**The 9th School/Conference Is Dedicated to the
65th Birthday of Professor Theo Geisel
of the Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, and University of Göttingen, Germany**

Professor Theo Geisel

Professor Theo Geisel is Managing Director of the Max Planck Institute for Dynamics and Self-Organization and Full Professor of Theoretical Physics at the University of Göttingen since 1996. He is also heading the Institute for Nonlinear Dynamics of the Georg August University Göttingen and was the founder and long-term chairperson of the Bernstein Center for Computational Neuroscience Göttingen. Born in 1948 he studied at the universities in Frankfurt and Regensburg and received his PhD in Theoretical Physics in 1975 from the University of Regensburg.

After his PhD studies he worked as a postdoc at the Max Planck Institute for Solid State Research in Stuttgart (1976-1977) and the Xerox Palo Alto Research Center (1978-1979). In 1980 he returned to his alma mater in Regensburg as an assistant professor, in 1983 he became a Heisenberg Fellow. The University of Würzburg recruited Theo Geisel as an associate professor in 1988 from where he left to join the Faculty of Physics at the University of Frankfurt in 1989. In 1996 the Max Planck Society hired him as a director of the Max Planck Institute for Fluid Dynamics, founded by Ludwig Prandtl in 1925, to guide it to new scientific directions. This eventually led to the scientific reorientation of the institute, now dedicated to the dynamics of complex matter, and to its renaming as Max Planck Institute for Dynamics and Self-Organization;

Professor Theo Geisel is widely recognized internationally for his cutting-edge research on nonlinear dynamics. He was the pioneer who discovered and introduced the stochastic process of Lévy Random Walks in 1985 and applied them in a variety of dynamical systems. On the one hand he has been working on problems originating in physics, like transport in nanostructures and quantum chaos, on the other hand he has applied methods from nonlinear dynamics to complex biological networks, the spreading of modern epidemics, and many problems in neuroscience that can be addressed by theoretical and computational methods.

Applying nonlinear dynamics to transport problems in semiconductor nanostructures he was able to explain numerous magnetoresistance effects, like e.g. a negative Hall effect and novel magnetoresistance peaks, by chaotic dynamics in mixed phase spaces. In the area of quantum chaos he elucidated the influence of classical chaos on fractal spectra in quasiperiodic Schrödinger systems and their localization transitions. He gave general quantum mechanical answers to the old questions, what determines the spreading of wave packets and what determines the decay of quantum mechanical correlations in such nontrivial cases with fractal or multifractal spectra.

His work, supported by the Leibniz-Prize 1994 and by the foundation of the Bernstein Center for Computational Neuroscience under his leadership, led to important and outstanding discoveries in neuroscience. He succeeded in developing the general theory for the emergence of neuronal maps in the visual cortex of mammals explaining many experimental details. These findings contributed substantially to the understanding of learning processes and the formation of neural circuits. He discovered the phenomenon of unstable attractors emerging generically in large networks of pulse-coupled oscillators. This appears to be a fundamental mechanism which allows neural systems to achieve the flexibility required to respond to ever changing inputs.

Furthermore, some 10 years ago Professor Geisel opened a new and original approach to the theoretical and empirical studies of human travel behaviour, the spreading of epidemics and related systems by analyzing the spreading of bank notes as a proxy and by introducing the notion of anomalous diffusion. His theoretical results explain the observed spreading behaviour and - very importantly - provide a basis for a largely improved precision for the prediction and forecast of epidemics.

In 1994 the German Research Foundation (Deutsche Forschungsgemeinschaft) awarded him the Gottfried Wilhelm Leibniz Prize, the most distinguished German research prize. A fellow of the American Physical Society (2008) and a member of the Göttingen Academy of Sciences and Humanities he received the Gentner-Kastler Prize in 2009, a prize which is awarded to a German physicist every second year by the French Physical Society and the German Physical Society.

Professor Theo Geisel is one of the five Honorary Directors of our Schools & Conferences, and one of the most outstanding invited lecturers since 1999. He is a pioneer of classical and quantum chaos and one of the most important founders of theoretical neurophysics, a scientific organizer and highly appreciated teacher and mentor. It is impressive to conclude that he has contributed important applications of dynamical systems to many of the scientific disciplines and research fields that are covered by the scientific programme of our School and Conference.

It is a great privilege to welcome and honour him at our 9th School and Conference in Maribor, on occasion of his 65th birthday, combining wonderful science with wonderful music. Also this cultural dimension is a part of his intellectual life, as he is an enthusiastic musician playing the saxophone and flute, e.g. in his institute's jazz band. It is on Tuesday 1 July 2014 at 19:00 that we shall celebrate his 65th birthday by a concert, laudatio, and the banquet.

Welcome Address by Siegfried Grossmann

Date: 6 May 2014

Respected Rector magnificus, Professor Rebolj,
Respected President of the EASA, Professor Unger,
Respected Director of the School/Conference Maribor 2014, Professor Robnik,
Distinguished Honorary Directors and Members of the Organizing Committee,
Professor Theo Geisel in particular,
Distinguished Speakers, Participants, and Friends,
Ladies and Gentleman!

Accept please this welcome address with my sincerest regards and all my best wishes for a fruitful and exciting event: *Let's Face Chaos through Nonlinear Dynamics.*

Let's face chaos: This meanwhile famous School/Conference has already a long and extraordinarily successful tradition and history. It is the success of the great idea, to have an attractive combination of a school and a conference: A school devoted to highest level teaching and because of that an exciting, most effective learning; a conference devoted to the exchange of most recent progress in various fields under the unifying headline of nonlinear, chaotic dynamics, our common field of longstanding scientific engagement.

This is the first time that for personal reasons I am unfortunately unable to participate, to contribute, to learn and listen as well as lecture myself.

I am sure that this 9th event will be as exciting, as vivid, as scientifically stimulating as all the eight previous ones. All this started in 1993, then organized in Ljubljana by a highly enthusiastic and extraordinary engaged student, Maja Malus, under the wise guidance of Marko Robnik, continuing already one year later and then for a while every two years, changing the location from Ljubljana to Maribor, stabilizing now as an every three years event in Maribor at the Drava. Many of you will feel like home meanwhile in this wonderful old, vivid City.

Looking at the program I am convinced that also this 9th *Letr's face chaos through nonlinear dynamics* meeting will be scientifically outstanding and highly attractive. And again it has an unusual cultural program too, as in all previous school/conferences, and it will take place as always simultaneously with the Lent-Festival, which many of us have visited as an exciting frame of an exciting scientific event.

I wish you a very good time here at the University of Maribor, during which you learn new, stimulating physics, listen to excellent talks, have fruitful discussions, get good ideas, meet many interesting people, can participate in the concert program and other events.

Have a wonderful stay in Maribor and with the School/Conference
And face Chaos through nonlinear dynamics!

Sincerely yours,
Siegfried Grossmann, thinking on you in absentia

Welcome Address by Hermann Haken

Dear participants, dear Marko, dear Theo,

I am sending you all my best wishes for a fruitful and pleasent meeting. Since I have wonderful remiscences of Marko's previous meetings *Let's Face Chaos through Nonlinear Dynamics*, I regret it deeply that I am unable to participate, but I want to contribute by some, partly historical, remarks. Since some time we observe an ever increasing splitting of science and technology into more and more highly specialised disciplines. The production of an overwhelming amount of knowledge is accompanied by a decrease of mutual understanding.

How can we deal with the ever increasing information flood? Clearly, there are attempts at managing knowledge production and retrieval by all kinds of institutions serving science by policy, or by the development of efficient search machines. But in my opinion the most important instrument is our human mind. What I mean is this. The most important and influential contributions to science are unifying concepts and theories. Just think of Mendelejew's periodic table of chemical elements, Maxwell's unification of electricity and magnetism, eventually including optics, Einstein's theory of space, time and matter, the development of quantum theory by Heisenberg and Schrödinger which forms the basis of most of modern technology, or the actual attempts at unified field theories, e.g. leading to the discovery of the Higgs particle.

Besides providing us with deep insights into the fundamental laws of nature, these theories make our handling of knowledge more economic. For instance, understanding one specific phenomenon helps us to understand or even to dicover a new one.

So far, these theories refer to physics and chemistry. But today, our scientific horizon widens.

We realize that concepts, models and mathematical methods originating from physics, can be fruitfully applied to biology, brain science, and many other fields ranging till economy and sociology. We discover that most of these disciplines are concerned with the collective behavior of the often numerous individual parts of a system. Nearly everywhere we deal with complex systems which in many cases share one surprising property: Their action is not a mere random superposition of the actions of their individual parts. Rather these systems are capable of forming spatial, temporal or functional structures, including those showing deterministic chaos.

How can we explain the spontaneous self-organized emergence of new qualities of a total system that are alien to its individual parts? Surely, while to a physicist some of these phenomena are strongly reminiscent of phase-transitions, today we also witness the development of exciting new ideas.

This and previous summer-schools and conferences *Let's face chaos through nonlinear dynamics* organized by Marko Robnik play a very important role in this scientific enterprise. The lectures and discussions among students and professors and the wonderful social frame will surely make also this meeting a great success.

Perhaps I may close with a personal reminiscence. In lectures I gave jointly with Robert Graham in 1969/70 I coined the term *Synergetics* to define an interdisciplinary field of research that studies the spontaneous formation of structures in non-equilibrium systems and tries to unearth underlying common principles.

You may understand my joy that your meeting contributes so much to the realisation of my original dream.

1st Week: 23 June - 28 June						
	MONDAY 23 June	TUESDAY 24 June	WEDNESDAY 25 June	THURSDAY 26 June	FRIDAY 27 June	SATURDAY 28 June
Chairman	*Robnik*	———	———	———	———	———
09:00 - 10:00	OPENING: Robnik, Rektor, Stanovnik	**Cvitanović**	**Cvitanović**	**Cvitanović**	**Cvitanović**	**Cvitanović**
10:00 - 11:00	**Cvitanović**	**Cvitanović**	**Cvitanović**	**Cvitanović**	**Cvitanović**	**Cvitanović**
11:00 - 11:30	– COFFEE & TEA –					
11:30 - 12:30	**Guhr**	**Guhr**	**Guhr**	**Guhr**	**Bountis**	**Bountis**
12:30 - 13:30	**Guhr**	**Guhr**	**Guhr**	**Bountis**	**Carbone**	
13:30 - 15:30	– LUNCH –					13:00 - 15:00 LUNCH
15:30 - 16:30	**Bountis**	**Bountis**	**Carbone**	**Carbone**	**Carbone**	15:00 - 16:45 **Sightseeing tour**
16:30 - 17:30			**Carbone**	**Carbone**	**Carbone**	16:45 - 18:30 **Wine tasting**
	19:00 **Concert & Banquet**	19:00 DINNER	19:00 DINNER	19:00 DINNER	19:00 DINNER	19:00 **Concert** 20:00 **Banquet**
		21:00-22:00 **Veble**				23:45 **Fireworks**

2nd Week: 30 June - 5 July

	MONDAY 30 June	TUESDAY 1 July	WEDNESDAY 2 July	THURSDAY 3 July	FRIDAY 4 July	SATURDAY 5 July
Chairman	*Robnik*	*Flach*	*Dvorak*	*McClintock*	*Prosen*	*Stefanovska*
09:00 - 10:00	**Haake**	**Geisel**	**Tass**	**Dvorak**	**Casati**	**Cvetič**
10:00 - 11:00	**Schmelcher**	**Rotter**	**Gilbert**	**Daido**	**Flach**	**Shock**
11:00 - 11:30	– COFFEE & TEA –					
11:30 - 12:30	**Takatsuka**	**Harayama**	**Aizawa**	**Stefanovska**	**Toda**	**Romanovski**
12:30 - 13:30	**Shudo**	**Stöckmann**	**Urbina**	**Schiepek**	**McClintock**	12:30-13:00 **Jason** 13:00-13:30 **Spiechowicz**
13:30 - 15:30	– LUNCH –					
Chairman	*Aizawa*	*Schmelcher*	*Casati*	*Gilbert*	*Toda*	
15:30 - 16:30	**Perc**	**Prosen**	**Robnik**	**Skokos**	**Marhl**	
16:30 - 17:00	**Stević**	**Buča**	**Batistić**	**Manos**	**Andresas**	
17:00 - 17:30	**Stević**	**Shiraishi**	**Nakagawa**	**Manos**	**Ferčec**	
19:00	DINNER	**Concert**	**Concert**	19:00-21:00 DINNER	19:00-21:00 DINNER	LAST DINNER
		Banquet	**Banquet**	21:00-22:00 **Stanovnik**	21:00-22:00 **Jerala**	23:45 **Fireworks**

Cultural, Social and Touristic Events

LENT FESTIVAL 2014

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 23 JUNE 19:00: OFFICIAL OPENING OF THE SCHOOL AND CONFERENCE WITH A CONCERT AND BANQUET

On Monday 23 June 2014 at 19:00 we shall gather in the ART Kavarna in the Hotel PIRAMIDA, to enjoy a concert by Barbara Upelj's quartet, followed by the opening speeches and the banquet.

TUESDAY 24 JUNE 2014 21:00: PUBLIC EVENING LECTURE BY PROFESSOR GREGOR VEBLE, PIPISTREL COMPANY AND UNIVERSITY OF NOVA GORICA

At 21:00-22:00 there will be a Public Evening Lecture delivered by *Professor Gregor Veble* from University of Nova Gorica, Slovenia, and the Pipistrel Company, Ajdovščina entitled *Automatic design of aerodynamic surfaces.*

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

SATURDAY 28 JUNE 2014: MARIBOR, WINE TASTING, CONCERT, BANQUET AND FIREWORKS

15:00-16:45 There will be a guided sightseeing 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.

16:45-18:00 Visit of the VINOTEKA ROŽMARIN with the wine tasting programme, testing the Slovenian Styrian wines.

19:00-20:00 Nejc Kamplet on piano will play for us selection of classical music. In the ART Kavarna in the Hotel PIRAMIDA.

20:00-23:45 Banquet

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

SUNDAY 29 JUNE 2014: AN EXCURSION TO PTUJ AND CASTLE, JERUZALEM AND PUH MUSEUM

On this day we organize an excursion which starts at 09:00 and we return to the residences in Maribor in the evening.

Departure from Maribor at 9.00 and ride by bus along the Drava Field to the oldest documented Slovenian town Ptuj. Visit of the castle which towers above the city and keeps many exhibits that represent the feudal culture of living between the 16th and 19th centuries and also collection of musical instruments, weapons, tapestries.... We shall walk through the old city center, past Orpheus monument and city tower, church of St Georg to the Town hall in front of which stands a statue of St. Florian, patron of firefighters and to the St. Francis Convent with church on the outskirts of the old city. Then we shall drive through the Ptuj Field towards the winegrowing hills of Jeruzalem. In the more than 300 year old vineyard cottage we shall have cold meal and wine tasting. In the afternoon we visit another attraction - the museum of inventor Janez Puh in place Sakušak - his hometown. In the museum are exhibited bicycles, motorcycles and other inventions of the famous inventor. Our trip will be completed in a pleasant tourist farm in the heart of the Slovenian hills with a dinner. Return to Maribor at about 20.00

The price per person is about 50EUR and includes all meals, wine and entrance tickets.

TUESDAY 1 JULY 2014: DEDICATED TO THE 65TH BIRTHDAY OF PROFESSOR THEO GEISEL, MAX-PLANCK-INSTITUTE FOR DYNAMICS AND SELF-ORGANIZATION AND UNIVERSITY OF GÖTTINGEN, GERMANY

This day is dedicated to the celebration of the 65th birthday of Professor Theo Geisel.

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

19:00-20:00 A concert by Urška Orešič (piano and vocal, jazz standards) about 60 minutes, in the ART Kavarna in the Hotel PIRAMIDA.

20:00-20:30 Laudatio for Professor Theo Geisel.

20:30-23:00 Banquet in the restaurant of Hotel PIRAMIDA.

WEDNESDAY 2 JULY 2014 20:00: CONCERT AND FESTIVE DINNER

19:00-20:00 Chamber music concert by the Feguš String Quartet.

20:00-23:00 Banquet

THURSDAY 3 JULY 2014 21:00: PUBLIC EVENING LECTURE BY ACADEMICIAN PROFESSOR BRANKO STANOVNIK, FACULTY FOR CHEMISTRY AND CHEMICAL ENGINEERING, UNIVERSITY OF LJUBLJANA

At 21:00-22:00 there will be a Public Evening Lecture delivered by *Academician Professor Branko Stanovnik* from the Faculty for Chemistry and Chemical Engineering, University of Ljubljana entitled *Heterocyclic compounds - Building blocks of life*

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

FRIDAY 4 JULY 2014 21:00: PUBLIC EVENING LECTURE BY PROFESSOR ROMAN JERALA, DEPARTMENT OF BIOTECHNOLOGY, NATIONAL INSTITUTE OF CHEMISTRY, LJUBLJANA

At 21:00-22:00 there will be a Public Evening Lecture delivered by *Professor Roman Jerala* from Department of biotechnology, National institute of chemistry, Ljubljana, entitled *Intelligent design: shaping cellular gene circuits and molecules in synthetic biology (with help from mathematicians and computer scientists).*

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

SATURDAY 5 JULY 2014: 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. Goodbye MARIBOR 2014! See you at MARIBOR 2017!

All events except for the trip on Sunday 29 June are free of charge for all invited lecturers and for other participants of the School and Conference, as they are covered by the participation fees and registration fees.

Organizing Committee

Director General and Chairman

Marko Robnik (CAMTP, Maribor, Slovenia)

Honorary Directors

Giulio Casati (Como, Italy)

Predrag Cvitanović (Atlanta, USA)

Theo Geisel (Göttingen, Germany)

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Valery Romanovski (CAMTP, Maribor, Slovenia)

Andreas Ruffing (Munich, Germany)

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Abstracts of Invited Lectures

Statistical aspects of weak chaos

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In non-hyperbolic dynamical systems, very slow dynamics is often generated, where the intrinsic features of weak chaos have been elucidated in the framework of the infinite ergodic theory. Universal aspects of weak chaos are reviewed carrying out with intermittent chaos and hamiltonian chaos. First, the nonstationarity of strong intermittency is described by some characteristic quantities, such as power spectral density, pausing time distribution, correlation function, Allan variance, 2-path correlation, etc. , which are successfully obtained from the renewal analysis in probability theory. However, the more detailed features in weak chaos can be derived by use of the infinite ergodic theorem, for instance, the Lyapunov exponent and the diffusion constant reveal inherent fluctuations obeying the Mittag-Leffler distribution. Secondly, the origin of slow dynamics (such as the Arnold diffusion) in hamiltonian systems is theoretically analysed based on the Nekhoroshev theorem, and it is shown that the pausing times universally obey the Log-Weibull distribution, and that the universal distribution clearly appears in some numerical simulations for high dimensional hamiltonian dynamics; in the cluster formation of gas molecules and in the FPU model of crystal lattice vibrations. Finally, a hamiltonian system, which manifests the infinite measure ergodicity, is discussed; the mixmaster universe model (Bianchi type IX) is completely analysed in terms of infinite ergodicity. This result seems to suggest that slow diffusions in generic hamiltonian cases might be also connected to infinite measure ergodicity, though we have not yet succeeded to find out the infinite ergodic sub-dynamics in the high dimensional systems.

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Lecture 1: Fundamental Concepts of Complexity Science

Tassos Bountis

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Complexity is a property of large systems, consisting of a huge number of units involving nonlinearly interacting agents, which exhibit incredibly complex behavior. New structures emerge out of non-equilibrium and order can be born out of chaos, following a process called self-organization. Complex systems in the Natural, Life and Social Sciences produce new shapes, patterns and forms that cannot be understood by studying only their individual parts. In this first lecture I will mention briefly how the Theory of Chaos and the Geometry of Fractals formed the mathematical foundation for this new science making us realize how complex behavior can arise in simple models of low dimensionality. I will speak, in particular about the properties of self-similarity under scaling, sensitive dependence on initial conditions and the concept of bifurcations that by the 1980s had already revolutionized our ideas about the relationship between dynamics and geometry in surprisingly small systems, paving the way for the remarkable advances of Complexity Science that were soon to follow.

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Lecture 2: Granular Dynamics, Bird Flocking and Chimera States

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One of the most challenging and important properties of complex systems is their ability to "condense", form clusters, flocks or subgroups, apparently spontaneously during their time evolution. As it turns out, this type of behavior is not at all accidental, but occurs as a result of an internal instability, due to which the system undergoes a global "bifurcation", that one may well characterize as a dynamical phase transition. In the case of granular material flowing down an array of periodically shaken boxes, as the inflow rate at the top increases, this instability is "announced" by the appearance of a back-propagating wavy pattern, followed by a catastrophic "particle jam" at the top of the array. In a group of birds, flocking is a global feature of many models imitating the fascinating patterns we see them form in the sky; and yet, when a "noise" parameter crosses a certain threshold, flocking breaks down by a phase transition, whose order remains to date a hotly debated issue. Finally, in the brain of many mammals the sudden appearance of neighboring synchronous and asynchronous neuronal ensembles, termed a "chimera state", is thought to be the result of a global bifurcation, which has been verified on a wide variety of oscillating networks with long range interactions. As we will discuss, these chimera states can now be observed in realistic *Hindmarsh Rose* models of neuron oscillators as well mechanical networks of coupled pendulum-like systems.

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Lecture 3: Order and Chaos in Multi-Dimensional Hamiltonian Systems

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Hamiltonian systems have been studied extensively by mathematicians and physicists for more than a century producing a wealth of theoretical predictions that have been thoroughly verified by numerical experiments. In the case of few degrees of freedom, one might claim that most of their properties are well understood. And yet, in many dimensions, there remain many secrets to be revealed and surprises to be discovered. In this lecture, I will first discuss the basic facts about Hamiltonian systems, using as an example the famous Fermi-Pasta-Ulam (FPU) $\beta-$ model consisting of a one-dimensional chain of coupled oscillators with harmonic and quartic nearest neighbor interactions. I will focus on the continuation of their (linear) normal mode periodic solutions and seek to relate their (local) stability to more global phenomena such as FPU recurrences and energy equipartition in the thermodynamic limit. I will extend the method of Lyapunov exponents to the spectrum of GALI_k indicators to study the breakdown of invariant tori. We will thus discover that low-dimensional phenomena connected with localization properties in configuration as well as Fourier space give rise to hierarchies of order (low dimensional invariant tori) and disorder (weakly and strongly chaotic domains) of great dynamical and statistical complexity that is only now beginning to be explored.

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Lecture 4: Complex Statistics of Hamiltonian Dynamics

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In this lecture we shall adopt an altogether different approach to the study of chaos in Hamiltonian systems. We will consider, in particular, probability distribution functions (pdfs) of sums of chaotic orbit variables in different regions of phase space, aiming to reveal the statistical properties of the motion in these regions. If the orbits are strongly chaotic, these pdfs tend to a Gaussian and the system quickly reaches an equilibrium state described by Boltzmann-Gibbs statistical mechanics. There exist, however, many interesting regimes of weak chaos characterized by long-lived quasi-stationary states (QSS), whose pdfs are well-approximated by q-Gaussian functions, associated with nonextensive statistical mechanics. Here, we will discuss such QSS for a number of N dof FPU models, as well as 2D area-preserving maps to locate such weakly chaotic QSS, investigate the complexity of their dynamics and discover their implications regarding the occurrence of dynamical phase transitions and the approach to thermodynamic equilibrium. Going beyond lattice dynamics, we will describe the occurrence of QSS in dynamical transitions observed in a microplasma model and explain how nonextensive statistics can help us distinguish strongly from weakly chaotic orbits in a barred galaxy model for short time intervals dictated by the limitations of the age of the universe.

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Lecture 5: Chaotic Diffusion and the Role of Long Range Interactions

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The absence of diffusion in disordered media, often called Anderson localization, is a general phenomenon that applies to the transport of different types of classical or quantum waves. An interesting question is what happens to the diffusion if nonlinearity is introduced. Currently, a greatly debatable problem concerns the long time spreading of the wave packet. It has been conjectured that chaotically spreading wave packets will asymptotically approach KAM torus-like structures in phase-space. In this lecture, we start by using the concepts of Nonextensive Statistical Mechanics to show that for a high-dimensional Klein-Gordon disordered particle chain, the dynamics does not relax onto a torus-like structure, but continues to spread chaotically along the chain for arbitrarily long times. Finally, we revisit our one-dimensional Fermi-Pasta-Ulam (FPU) model and examine the role of short vs. long range interactions, by coupling all particles by quartic interactions whose coupling coefficients decay as $1/r^{\alpha}$ ($\alpha \geq 0$). Our computations show that (i) for $\alpha > 1$ the maximal Lyapunov exponent remains finite and positive for increasing numbers of oscillators, whereas, for $0 \leq \alpha \leq 1$, it asymptotically vanishes. (ii) The distribution of time-averaged velocities is Maxwellian ($q = 1$) for α large enough, whereas it is well approached by a q-Gaussian with the index $q(\alpha)$ decreasing to one, as α increases from zero to infinity, suggesting a remarkable transition from Boltzmann-Gibbs (BG) to Tsallis thermostatistics as we move from short range ($\alpha > 1$) to long range interactions ($\alpha < 1$).

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Mathematical modeling of complex systems

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These 5 lectures are meant to be introductory, with the main ideas presented in a pedagogical way by means of simple examples. They are aimed primarily at graduate students interested in complex phenomena occurring in various disciplines. In the first 2 lectures, we will be concerned with the emergence of collective behavior in the form of clustering, flocking, synchronization, etc. as they occur in dissipative systems of interest to Physics and Biology. Our approach will be to start from some crucial observation or experiment and seek to construct the appropriate mathematical model that captures the main features of the data. The remaining 3 lectures will focus on a class of conservative systems described by N-degree of freedom Hamiltonian functions, which are familiar to us from classical mechanics, astronomy and solid state physics. Our main point will be to show that despite a well established general theory, there are still many important local phenomena involving various degrees of order and chaos that need to be further understood, because of their global consequences regarding the physical properties of the system, especially for long times and large N. We will thus discover that to understand these complex aspects of Hamiltonian models, we need to combine the mathematical techniques of nonlinear dynamics with a statistical analysis of probability distributions of chaotic orbits in different regimes of the multi dimensional phase space, where the motion of the system evolves.

Challenges in Complex Systems: in particular in socio/economic sciences

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The lectures (7h) are organized in two main parts: Part I will be devoted to the broad initiative 'FuturICT', Part II will be devoted to the applications of fractal geometry for the analysis of big-data sets of socio-economic-enviromental interest.

Part I: Global Community for our Complex connected World

FuturICT is a visionary project that will deliver new science and technology to explore, understand and manage our connected world. This will inspire new information and communication technologies (ICT) that are socially adaptive and socially interactive, supporting collective awareness.

Our increasingly dense interconnected world poses every day new challenges that need to be approached in several dimensions, at different temporal and spatial scales. In particular, given the scope and scale of the world's future Internet of everything, new technologies with the lowest energetic impact, unconventional computational schemes, novel phenomena and paradigm should be figure out for understanding and managing such increasing complexity. Revealing the hidden laws and processes underlying our complex, global, socially interactive systems constitutes one of the most pressing scientific challenges of the 21st Century. Integrating complexity science with ICT and the social sciences, will allow us to design novel robust, trustworthy and adaptive technologies based on socially inspired paradigms. Data from a variety of sources will help us to develop models of techno-socioeconomic systems. In turn, insights from these models will inspire a new generation of socially adaptive, self-organised ICT systems. This will create a paradigm shift and facilitate a symbiotic co-evolution of ICT and society. Further info at www.futurict.eu

Part II: A non-Random Walk through our complex connected world

Time series are a tool to describe biological, social and economic systems in one dimension, such as stock market indexes and genomic sequences. Extended systems evolving over space, such as urban textures, World Wide Web and firms are described in terms of high-dimensional random structures.

A short overview of the Detrending Moving Average (DMA) algorithm is presented. The DMA has the ability to quantify temporal and spatial long-range dependence of fractal sets with arbitrary dimension. Time series, profiles and surfaces can be characterized by the fractal dimension D, a measure of roughness, and by the Hurst exponent H, a measure of long-memory dependence. The method, in addition to accomplish accurate and fast estimates of the fractal dimension D and Hurst exponent H, can provide interesting clues between fractal properties, self-organized criticality and entropy of long-range correlated sequences. Further readings and tips about the DMA algorithm at www.polito.it/noiselab

Classical dynamical localization

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We consider a class of purely classical kicked rotor models, designed so that kicks can change their momenta only by multiples of a constant. Their classical dynamics is numerically found to display slow logarithmic growth of momentum, or quadratic growth of energy, depending on the arithmetic nature of the constant. Such features mimic paradigmatic features of the standard quantum kicked rotor, notably dynamical localization in momentum, or quantum resonances, depending on the arithmetic nature $\hbar$ Such results command a reconsideration of generally accepted views, that dynamical localization and quantum resonances are a result of quantum interference

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String theory, particle physics and black holes

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In past decades, string theory has emerged as the prime candidate for a quantum unification of electromagnetic, nuclear and gravitational forces. Geometrical aspects of string theory, and in particular the existence of extra dimensions, shed light on important fundamental questions, including the microscopic structure of black holes and the geometric origin of particle physics. We review certain aspects of these developments such as introduction of extended objects - Dirichlet branes - and highlight an important geometric role that these objects play in deriving particle physics from string theory and review the role these objects play in elucidating the microscopic structure of black holes. We highlight the most recent progress made in deriving particle physics from F-theory, a string theory at finite coupling. We also review progress made on studies of internal structure of non-extremal black holes in string theory via so-called subtracted geometry.

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Introduction to nonlinear dynamics

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Lecture 1 & 2: 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.

The lecture notes and videos are available online, as parts of the advanced nonlinear dynamics course, `ChaosBook.org/version15/Maribor13.shtml`

Lecture 3 & 4: 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.

Lecture 5 & 6: Noise is your friend

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.

Lecture 7 & 8: 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.

Lecture 9 & 10: Dynamical theory 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.

Aging transition and other phenomena in large populations of dynamical units

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Dynamic activity such as periodic oscillation and chaos exhibited by large populations of coupled dynamical units plays an important role in many fields of science and technology. A crucial issue is to examine its robustness against the deterioration of those units caused by aging, accidents, and so on. The present talk will be concerned with theoretical studies of this issue, focusing on such a case that each unit remains active (i.e., self-oscillatory) until the deterioration makes it inactive (i.e., not self-oscillatory).

There are two typical scenarios for the onset of oscillation in a single unit: One is a Hopf bifurcation and the other what is called an SNIC (saddle-node bifurcation on an invariant circle). We begin with the case in which each unit follows the former scenario and review main results published so far on the behavior of the whole system as the ratio of inactive units increases (this process is defined to be *aging*). The most striking phenomenon is a transition of the system from the dynamic phase to the static which occurs when the ratio exceeds a critical value, termed an *aging transition*. Some other interesting phenomena will also be treated.

We then go on to the case of the latter scenario. A unique feature of this case is that a single unit can show *excitability* depending on the value of its bifurcation parameter. Although relevant to a number of areas, this feature is particularly important in biological and physiological contexts. Here we examine the behavior of a few populations, each composed of such units with a uniform distribution of the bifurcation parameter, by varying the mean value of the distribution as well as the coupling strength. Some model-independent results will be highlighted.

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Water transport in the early planetary system

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For an estimate of water transport in the early planetary system we investigate the degree of possible water delivery by means of asteroid collisions. Here we present a study of the distribution of impact velocities and angles of small bodies with a certain water content and initial mass of a tenth lunar mass that are distributed on orbits with semimajor axes between 1 and 2 AU, small eccentricities $e < 0.15$ and small inclinations. The bodies' initial water (ice) content increases with their distance to the Sun from 0.5 % to 3 %. By simulating mutual collisions via n-body calculations we trace how the masses and water contents of those bodies evolve depending on the presence of a perturbing Jupiter-like planet in different distances. We find that within 1 Myr the masses of the bodies increase up to one lunar mass and the inclination-distribution is widened while the water content closer to the Sun tends to increase from inward scattered objects. We also present means of verification of our present perfect merging assumption via simulating the collision processes using Smooth Particle Hydrodynamics (SPH).

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Perturbing Flat Bands

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Macroscopically degenerate flat bands (FB) in periodic lattices host compact local- ized states which appear due to destructive interference and local symmetry. Interference provides a deep connection between the existence of flat band states (FBS) and the appearance of Fano resonances for wave propagation. I will introduce generic transformations detangling FBS and dispersive states into lattices of Fano defects. Inverting the transformation, one can generate a continuum of FB models. That procedure allows to systematically treat perturbations such as disorder, quasiperiodic potentials, magnetic fields, nonlinearity and quantum many body interactions. The presence of weak uncorrelated disorder leads to the emergence of energy-dependent localization length scaling due to Fano resonances and renormalized disorder distributions with heavy Cauchy tails. In the presence of strong but correlated disorder (which respects the local FBS symmetry) logarithmic or square root singularities develop in the density of states around the FB energy due to quadratic energy renormalization of eigenstates. For strong quasiperiodic (Aubry-Andre) potential perturbations we obtain analytical expressions for the energy dependence of metal-insulator transitions (mobility edges). I will also present first results on the impact of magnetic fields, nonlinearity, and interactions between quantum particles on the FB and the FBS.

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Prospects and challenges of neurophysics: A physicist's view after 25 years

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As you read these lines, millions of neurons are active in your brain and communicate with each other by sending short pulses. It is a major aim and formidable challenge for neurophysics to understand the collective dynamics of large biological neural networks in order to determine how they carry out complex computations. This talk presents the challenges, prospects, and progress in pursuing this aim from the view of a physicist who has been observing the field over the last 25 years.

With recent advances of experimental techniques, the activity of large numbers of cells can now be monitored in parallel and with single cell resolution, even in freely moving animals. These techniques together with targeted optogenetic stimulation promise to considerably advance our insight into the function of collective neuronal dynamics in the near future.

Making sense of these huge data sets, however, requires theory, but these networks exhibit features that let them elude standard theoretical treatments. For example, the units of the network interact asymmetrically and at discrete times only, i.e. not continuously as in conventional many-body theory in physics. There are significant interaction delays, which formally make the systems infinite-dimensional. Complex connectivities give rise to novel multi-operator problems, for which new methods based on graph theory have been devised to obtain rigorous analytic results. Theoretical progress has already uncovered novel and amazing properties of nonlinear dynamics exhibited by such networks and is impacting experimental neuroscience.

Time reversibility, phase-space contraction rate and the second law of thermodynamics

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The Gallavotti-Cohen fluctuation theorem, which concerns a non-trivial symmetry of the steady states of some thermostated systems driven out of equilibrium, is among a number of intriguing theoretical results which were discovered some twenty years ago and have since had great influence on the field of non-equilibrium statistical physics, in particular with respect to the microscopic origin of the second law of thermodynamics—in other words, irreversibility.

Central to the relevance of the fluctuation theorem to non-equilibrium statistical mechanics is the identity between the phase-space contraction rate of thermostated systems and their entropy production rate (as specified by non-equilibrium thermodynamics). This identity, whose generality is by no means obvious, stems from the precise mechanism through which the 'thermostat' constantly removes energy from such systems when they are acted upon by an external forcing.

In this talk I shall review some of the key developments of this theory and offer a new, albeit modest, contribution in the form of the following analytic result: simple two-dimensional triangular maps that, for elementary reasons, verify the Gallavotti-Cohen symmetry, typically break the identity between phase-space contraction and entropy production rates. I will provide a number of examples of such systems and show that the difference between those two quantities is usually small and may in fact be rather difficult to detect through numerical measurements.

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!

In the last 15 or 20 years, the physicists' interest in economic 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. 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. From a more practical viewpoint, the need to quantitatively improve risk management in economics is a driving force in econophysics.

The presentation starts from scratch, no background in economics is needed, it consists of five lectures: (1) Basic Concepts, (2) Detailed Look at Stock Markets and Trading, (3) Financial Correlations and Portfolio Optimization, (4) Quantitative Identification of Market States, (5) Credit Risk.

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.

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Selfaveraging characteristics of spectral fluctuations

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The spectral form factor as well as the two-point correlator of the (quasi-)energy density of individual quantum dynamics are known not to be selfaveraging, even in the semiclassical limit. Only suitable smoothing turns them into reliable characteristics of spectral fluctuations. We present numerical data for two types of smoothing for a fully chaotic kicked top. One method uses imaginary parts of the quasi-energy variables while the other employs primitives of form factor and correlator. Universal behavior is found for the smoothed form factor and also for the correlator within quasi-energy ranges where correlations persist above a certain noise level. Noise is revealed as such by strong non-selfaveraging: Tiny changes of the effective Planck constant entail large changes in the smoothed spectral characteristics. Theoretical "predictions" of RMT behavior of spectral correlations outside the range now established appear to implicitly involve averages over ensembles of quantum systems sharing the same classical limit. Further theoretical work avoiding such $\hbar$-averages and aiming at selfaveraging spectral characteristics appears desirable.

Applications of Chaotic Billiard Lasers: Single Mode Operation and Compact Long Optical Paths

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For the last two decades, the research field of quantum chaos has involved two-dimensional (2D) microcavity lasers, which connected the mathematical chaotic billiard models with the actual devices and experimentally demonstrated the theoretical results of quantum chaos such as chaos-assisted tunneling. Here we call those 2D microcavity lasers whose ray dynamics is completely chaotic or partially chaotic “chaotic billiard lasers”. Although integrable billiard lasers like microdisk lasers of circular shape and broad area lasers of rectangular shape have found practical applications for sensors and optical components, most of the researches on chaotic billiard lasers still remain fundamental. By both the experimental and theoretical results, we shall show the possibilities of novel and practical applications of chaotic billiard lasers for single mode operation and compact long optical paths.

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Intelligent design: shaping cellular gene circuits and molecules in synthetic biology (with help from mathematicians and computer scientists)

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Biological systems are complex systems for the exchange of energy and molecules using coordinated action of biopolymers. Most of the biopolymers that perform different activities are proteins, composed of a defined amino-acid sequence, which is encoded in the genes by the sequence of DNA constituting the cellular genome. Activation of each gene is regulated by transcriptional factors, proteins that bind to the selected sequences of each gene and activate or repress its transcription. Since genes can also code for transcriptional factors cellular genome can constitute complex regulatory networks, including feedback loops. If we want to harness cells to perform different functions, such as sensors or therapeutic devices we should be able to engineer cells for a predictable response to selected inputs, different from the existing cellular networks. Instead of relying on natural regulatory elements we selected to use designable modular DNA binding proteins, called TALEs, that can bind to almost any selected DNA sequence. The advantage of this approach is that we can make thousands of DNA binding domains. This allowed construction of genetic NOR gates in mammalian cells, each of which required two TALE proteins. Those logic gates can be introduced into cells through the synthetic recombinant DNA. NOR gate represents a functionally complete logic gate, which can be used to make any selected logic function. We demonstrated functionality of all 16 designed two-input logic gate in mammalian cells. Moreover TALEs also allow us to make bistable switch, where we needed to introduce nonlinearity by a feedback loop and competition. The ubiquitous use of proteins as smart materials in nature is based on their ability to self-assemble into a large number of different folds. Natural protein folds are very difficult to predict and design, since they depend on a large number of weak cooperative interactions among amino-acid residue constituents of polypeptides. We invented a new type of topological protein fold, which is based on assembling modular pairwise interacting segments called coiled-coil domains. We can design the selectivity of coiled-coil segments based on simple rules. The goal was to design the polyhedra, where each of their edges is composed of a coiled-coil dimer. Polyhedron is therefore self-assembled from a single chain that traverses each edge of the polyhedron exactly twice with some additional restrictions to ensure the stability of the polyhedron and compatibility with protein stability rules. The self-assembly is defined by the order of concatenated coiled-coil dimer-forming segments, that can form parallel or antiparallel dimers. This ability to select orientation allows prepare, in principle, any type of a polyhedron from polypeptides. We experimentally demonstrated this concept by making a polypeptide tetrahedron cage with 5 nm edges. The essence of synthetic biology is to design devices and molecules present in nature that have new interesting properties, but it also allows us to investigate the mechanisms of natural processes.

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Chaos and dynamical trends in barred galaxies: bridging the gap between time-dependent analytical models and N-body simulations

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Self-consistent N-body simulations are efficient tools to study galactic dynamics. However, using them to study individual trajectories (or ensembles) in detail can be challenging. Such orbital studies are important to shed light on global phase space properties, which are the underlying cause of observed structures. The potentials needed to describe self-consistent models are time-dependent. I will present a study on the distinction and quantification of chaotic and regular motion in a time-dependent Hamiltonian barred galaxy model and the role of the interplay between chaotic and regular behavior of star orbits as the parameters of the model evolve in time. A new way of using the GALI method as a reliable criterion to estimate the relative fraction of chaotic vs. regular orbits in such time-dependent potentials is here applied. I will then discuss the dynamical properties of a non-autonomous galactic system, whose time-dependent potential adequately mimics certain realistic trends arising from N-body barred galaxy simulations. Starting with its reduced time-independent 2-degrees of freedom model, I will show charts with different islands of stability (associated with certain orbital morphologies) and chaotic regions. In the full 3-degrees of freedom time-dependent case, I will show representative trajectories experiencing typical dynamical behaviors, i.e. interplay between regular and chaotic motion for different epochs. Finally, I will discuss its underlying global dynamical transitions, estimating fractions of (un)stable motion of an ensemble of initial conditions taken from the simulation and evolved with the time-dependent analytical potential. For such an ensemble, it turns out that the fraction of regular motion increases with time.

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Evolutionary Aspects of Fine-Tuning of Cellular Oscillators in the Networks

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Abstract

It is becoming progressively more evident that the understanding of the functioning of biological tissues does not only rely on the knowledge of individual cell behaviour, but requires thorough investigations of the mutual interactions among the cells [1]. There are examples where particular tissue dysfunctions cannot be explained on the basis of alterations in individual cells but the pathology results from changes in interconnections between the cells [2]. Mathematical modelling of the network dynamics is a convenient toll for analysing the role of individual cells and the emergent properties of the tissue. In particular, modelling of complex cellular oscillators in the networks plays important role. A decade ago we showed that individual oscillators exhibit different levels of flexibility, which characterizes their stability and susceptibility to external perturbations [3, 4]. We have elevated this knowledge to networks of cellular oscillators, and showed that cellular oscillators with different flexibility match different optimal topologies of the networks in which they provide their maximal coordination and efficiency [5]. The phenomenon relies on the remarkable fact that individual oscillators in the network change their flexibility, a kind of dynamical flexibility, in dependence on the wiring in the network. From the evolutionary point of view we might hypothesise that this fine-tuning of oscillators and their wiring in the network structures of appropriate topologies can be understood as a trade-off between minimal costs for individual oscillator regulation and maximal efficiency in the wiring of these oscillators in the network. Moreover, our current studies indicate that cell failures and the risk of kicking-off particular nodes in the network might play crucial role in the evolution of biological tissues. We provide model predictions indicating the importance of evolutionary developed robustness of biological tissues to random and targeted attacks. This study is conducted for networks of different topologies and cellular oscillators with different flexibilities. The results provide a clear evidence of natural optimisation, a trade-off between the efficiency and robustness.

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How ions get through biological ion channels

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We outline very briefly the role and function of biological ion channels: the natural nanopores that provide for fast and selective permeation of physiologically important ions (e.g. Na^+, K^+ and Ca^{2+}) through cellular membranes. Although a great deal is now known about ion channels, including their detailed atomic structure in some cases, this information has helped surprisingly little in understanding how they actually work: the central conundrum – their ability to conduct almost at the rate of free diffusion while remaining highly selective for particular ions – remains largely unresolved. It is known, however, that the channel's conductive properties are determined mainly by a short negatively-charged selectivity filter. We report recent progress in treating permeation as a problem in nonlinear dynamics under electrostatic and stochastic forces. We point out that, remarkably, the process is closely analogous to mesoscopic conduction in quantum dots. We discuss how this approach is able to account for the conduction bands recently discovered in Brownian dynamics simulations, for valence selectivity, and for unexpected changes in selectivity that occur when the charge at the selectivity filter is altered by mutation. We conclude by discussing the implications for the design of artificial nanopores.

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Bargaining with discrete strategies

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Imagine two players having to share a sum of money. One proposes a split (p), and the other can either agree with it or not (q). No haggling is allowed. If there is an agreement, the sum is shared according to the proposal. If not, both players remain empty handed. This is the blueprint of the ultimatum game [1]. Seminal experiments on ultimatum bargaining have revealed that humans are remarkably fond of fair play [2]. When asked to share something, unfair offers are rare and their acceptance rate is small. Traditionally, the ultimatum game has been studied with continuous strategies, and it has been shown that empathy and spatiality may lead to the evolution of fairness [3]. However, evolutionary games with continuous strategies often hide the true complexity of the problem, because solutions that would be driven by pattern formation are unstable. Discrete strategies in the ultimatum game open the gate to fascinatingly rich dynamical behavior. The phase diagram with continuous and discontinuous phase transitions as well as a tri-critical point, reveals the hidden complexity behind the pursuit of human fair play [4].

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Integrable non-equilibrium steady-state density operators and exact bounds on quantum transport

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I will explain a fundamental connection between integrability of non-equilibrium steady states of boundary driven markovian master equations for interacting quantum chains and existence of quasi-local conserved operators which lie outside the standard quantum inverse scattering theory. Namely, the novel conservation laws are expressed in terms of a family of *nonhermitian* (and non-normal, non-diagonalizable) commuting quantum transfer operators. I will then show how existence of quasi-local conserved operators can be implemented to yield strict lower bounds on transport coefficients, such as Drude weights or even diffusion constants.

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Quantum localization of chaotic eigenstates and the statistics of energy spectra

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Quantum localization of classical chaotic eigenstatets is one of the most important phenomena in quantum chaos, or more generally - wave chaos, along with the characteristic behaviour of statistical properties of the energy spectra. Quantum localization sets in, if the Heisenberg time t_H of the given system is shorter than the classical transport times of the underlying classical system, i.e. when the classical transport is slower than the quantum time resolution of the evolution operator. The Heisenberg time t_H, as an important characterization of every quantum system, is namely equal to the ratio of the Planck constant $2\pi\hbar$ and the mean spacing between two nearest energy levels ΔE, $t_H = 2\pi\hbar/\Delta E$.

We shall show the functional dependence between the degree of localization and the spectral statistics in autonomous (time independent) systems, in analogy with the kicked rotator, which is the paradigm of the time periodic (Floquet) systems, and shall demonstrate the approach and the method in the case of a billiard family in the dynamical regime between the integrability (circle) and full chaos (cardioid), where we shall extract the chaotic eigenstates. The degree of localization is determined by two localization measures, using the Poincaré Husimi functions (which are the Gaussian smoothed Wigner functions in the Poincaré Birkhoff phase space), which are positive definite and can be treated as quasi-probability densities. The first measure A is defined by means of the information entropy, whilst the second one, C, in terms of the correlations in the phase space of the Poincaré Husimi functions of the eigenstates. Surprisingly, and very satisfactory, the two measueres are linearly related and thus equivalent.

One of the main manifestations of chaos in chaotic eigenstates in absence of the quantum localization is the energy level spacing distribution $P(S)$ (of nearest neighbours), which at small S is linear $P(S) \propto S$, and we speak of the linear level repulsion, while in the integrable systems we have the Poisson statistics (exponential function $P(S) = \exp(-S)$), where there is no level repulsion ($P(0) = 1 \neq 0$). In fully chaotic regime with quantum localization we observe that $P(S)$ at small S is a power law $P(S) \propto S^{\beta}$, with $0 < \beta < 1$. We shall show that there is a functional dependence between the localization measure A and the exponent β, namely that β is a monotonic function of A: in the case of the strong localization are A and β small, while in the case of weak localization (almost extended chaotic states) A and β are close to 1.

We shall illustrate the approach in the model example of the above mentioned billiard family, where we can separate the regular and chaotic states. This presentation is based on our very recent papers.

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Integrability of autonomous systems of ordinary differential equations

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The problem of finding systems with one or few independent first integrals inside families of autonomous systems depending on parameters is discussed. Methods to construct first integrals or prove their existence in such systems are reviewed. Among them the main attention is paid to the Poincare-Dulac normal form method, the Darboux method and the interconnection of integrability and time-reversibility. An efficient computational technique to the problem of finding first integrals is proposed. Some examples of application of the theory and the computational approach are presented.

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New insights on coherent wave transmission through disordered systems

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In the first part of my talk I will speak about our theoretical and experimental studies on microwave scattering through systems which are so strongly disordered, that the effect of Anderson localization suppresses all but a single transmission channel [1]. As a result, we can describe the entire disordered sample in this deeply localized limit as an effective 1D system with a renormalized localization length. We show that the dominant transmission channel is formed by an individual Anderson-localized mode or by a so-called "necklace state".
In a second project, we study the wave transmission through wave guides with surface corrugations [2,3]. We show that for a quantitatively accurate description of such a situation, scattering processes need to be taken into account which are of higher order in the surface corrugation amplitude than those which are conventionally considered. Including these higher-order terms, we are able to provide fully analytical expressions for the multi-mode wave guide transmission which are in excellent agreement with numerical results [2]. Based on this comprehensive approach we find and explain pronounced reflection resonances in wave guides with a step-like surface profile – a robust effect which has been overlooked in previous studies of the same system. I will also explain how these insights allow us to design wave guides with transmission band gaps in predetermined frequency intervals [3].
In the last part of my talk I will explain how surface-disordered mirrors can be used to study ultra-cold neutrons bouncing in the gravitational field of the earth [4]. The quantized energy levels of these gravitationally bound neutrons can be employed for gravity resonance spectroscopy – a new technique to measure the law of gravity at short distances which is accurate enough to provide stringent constraints on certain scenarios for deviations from the Newtonian law of gravity.

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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.

A Lie-algebraic concept for obtaining basic adaptive discretizations is explored.

Some of the moment problems of the underlying basic difference equations are investigated. Applications to discrete Schrödinger theory are worked out and some spectral properties of the arising operators are presented, also in the case of Schrödinger operators with basic shift–potentials and in the case of ground state difference–differential operators.

For the arising orthogonal function systems, the concept of inherited orthogonality is explained. The results in this talk are mainly related to a recent joint work with Sophia Roßkopf and Lucia Birk.

Following a suggestion by Hans–Jürgen Stöckmann, the analogous situation on an equidistant lattice has now been worked out and leads to some amazing effects. These new results will also be presented.

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Chaos and Self-Organization in Human Change Processes

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Synergetics has arrived in psychology. More than this - it has proven to be an inspiring research paradigm for investigating and modelling complexity and dynamics of mental, behavioural, and social phenomena. The evolution of human systems is characterized by features as circular causality, the emergence and dynamics of order parameters, order transitions, and critical instabilities. Psychotherapy research was one of the most productive fields for empirical research on self-organization in psychology. Referring to several studies on psychotherapy processes we will demonstrate that human development and learning generate some kind of order. They are chaotic in a strict sense, i.e., they can be characterized by low-dimensional, complex, and changing dynamics. Other studies using different data sources, coding methods, and time scales focus on synchronization, non-stationarity, and local instabilities of psychotherapeutic processes. By this way and referring to the concept of order transitions, Synergetics offers an explanation to what is called sudden changes in psychotherapy. The internet-technology of the Synergetic Navigation System (SNS) allows for an application of these results and a feedback-based, data-driven control of therapeutic self-organization processes. Empirical evidence also exists for coordinated order transitions in the dynamics of subjective experiences and brain activity, measured by repeated fMRI scans. During the treatment of patients with obsessive-compulsive disorder (OCD), transitions started by the destabilization of current patterns and hence by critical fluctuations. The most important change rates of neural activity in different brain areas occurred during cognitive-affective order transitions.

Beyond the Parity and Bloch Theorem: A Systematic Pathway to the Breaking of Discrete Symmetries

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The parity and Bloch theorems are generalized to the case of broken global symmetry. Local inversion or translation symmetries are shown to yield invariant currents that characterize wave propagation. These currents map the wave function from an arbitrary spatial domain to any symmetry-related domain. Our approach addresses any combination of local symmetries, thus applying in particular to acoustic, optical and matter waves. Nonvanishing values of the invariant currents provide a systematic pathway to the breaking of discrete global symmetries. As examples of application we provide a classification of perfectly transmitting resonances in completely locally symmetric scattering setups. This includes sum rules on the invariant currents that provide resonance conditions.

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Strongly Coupled Field Theories and the Holographic Principle

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In this overview talk I shall discuss some of the progress made over the last 15 years in using string theory techniques to understand strongly coupled field theories. In particular I will discuss the AdS/CFT correspondence which tells us that a strong coupled and conformal field theory in four dimensions, has an alternative description as a weakly coupled theory of gravity in a higher dimensional curved space-time. This work has led to remarkable insights into Quantum Chromodynamics, Condensed Matter Physics, the emergence of space-time, the encoding of information in field theories, and much more besides. There is much which has been learnt and which is still to be learnt in relation to integrable theories using these holographic techniques and I will point out some of the directions which are on the cutting edge of this research topic

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Renormalized perturbative analysis of mixed quantum systems and dynamically induced diffraction

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Diffraction occurs in wave dynamics when an obstacle prevents smooth propagation of wave. More generally, if the system has a discontinuous or indifferentiable points not only in configuration space but in phase space, diffractive effects come into play. The so-called mushroom billiard is a typical example in which strictly sharp borders dividing regular and chaotic regions appear in phase space, and induces diffraction in the corresponding quantum mechanics.

Diffraction is a purely wave mechanical phenomenon since it is a transition to classical mechanically inaccessible regions, analogous to tunneling effects in quantum mechanics. However, we here distinguish diffraction from tunneling in respect of the validity of the leading-order semiclassical (WKB) approximation. Alternatively stated, we regard tunneling as a process that could be described by classical dynamics, whereas diffraction is beyond any interpretation based on classical dynamics.

The aim of the present talk is to show that diffraction is a main driving force causing the classically forbidden processes even in purely analytic systems, such as the standard or Hénon map. The situation we focus on is the system with mixed phase space, in which *dynamical tunneling* has so far been believed to control purely quantum phenomena. Our analysis is based on a renormalized perturbation theory using the Baker-Campbell-Hausdorff (BCH) expansion, and it is shown that the mismatch between classical KAM curves and the curves predicted by the shadow Hamiltonian appearing in the BCH expansion is a source of diffraction thus induced.

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Chaotic behavior of disordered nonlinear lattices

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First I shall briefly review some basic results on the effect of nonlinearity on wave packet spreading in one–dimensional nonlinear disordered lattices. I will describe the statistical characteristics of energy spreading in such systems and provide evidence that nonlinearity destroys localization. For this purpose I will consider the disordered variants of two typical one–dimensional Hamiltonian lattice models: the Klein-Gordon (KG) oscillator chain, and the discrete nonlinear Schrödinger equation (DNLS).

Then I shall present some recent results concerning the deeper understanding of the chaotic behavior of the disordered KG model. In particular, I will discuss computations of the time dependence of the maximum Lyapunov exponent and of the distribution of the associated deviation vector, which show a slowing down of chaotic dynamics. Nevertheless, a cross over into regular dynamics does not occur to the largest observed time scales, since chaos remains fast enough to allow the thermalization of the spreading wave packet. Strongly chaotic spots, which meander through the system as time evolves, play a central role in this phenomenon. These findings confirm that nonequilibrium chaos and phase decoherence persist, fueling the prediction of a complete delocalization.

At the end of my talk, I will present some recently developed high order symplectic integrators for Hamiltonian systems that can be split in three different integrable parts, instead of the usual case of two part split considered in traditional symplectic schemes. These new schemes proved to be ideal for the accurate integration of the DNLS model for very long time intervals in feasible CPU times. Such symplectic methods could provide effective means to numerically study the asymptotic behavior of wave packet spreading in the DNLS model; a hotly debated subject in current scientific literature.

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Heterocyclic compounds - Building blocks of life

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Heterocyclic compounds are very widely distributed in Nature and are essential to life; they play a vital role in the metabolism of all living cells. For example, the following are heterocyclic compounds: the pyrimidine and purine bases of the genetic material DNA; the essential amino acids proline, histidine and tryptophan; the vitamins and coenzyme pecursors thiamine, riboflavine, pyridoxine, folic acid and biotin; the B12 and E families of vitamins, the photosynthesizing pigment chlorophill; the oxygen transporting pigment hemoglobin and its breakdown products the bile pigments; the hormones kinetin, heteroauxin, serotonin, histamin and methoxatin, and most of the sugars. There are a vast number of pharmacologically active heterocyclic compounds, many of which are in regular clinical use. Some of these are natural products, for example antibiotics, such as penicillin and cephalosporin, alkaloids such as vinblastine, ellipticine, morphine and reserpin, and cardiac glycosides such as those of digitalis. However, the large majority are synthetic heterocyclics which have found widespread use as anticancer agents, analgetics, hypnotics and vasopressor modifiers, and as pesticides, insecticides, weedkillers and rodenticides [1,2].

There are also a large number of synthetic heterocyclic compounds with other important practical applications, as dyestuffs, copolymers, solvents, photographic sensitizers and developers, as antioxidants and vulcanization accelerators in the rubber industry, and many are valuable intermediates in synthesis [1,2].

Some examples of modern synthetic procedures, cyclizations, rearrangements and other ring transformations will be presented [2].

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Chronotaxic systems: A journey from the cell to the brain treated as ensembles of nonautonomous dynamical systems

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One of the main characteristics of living systems is their ability to exchange energy and matter with the environment, classifying them as thermodynamically open systems which have often been treated as stochastic. The main features of such systems are their ability to interact with other systems in the environment, and their complexity. The dynamics of these interactions is therefore one of the key features that become lost if the system is studied in isolation. Furthermore, the interactions result in variability in the rate of exchange of e.g. substances, which must be continuous, resulting in the time-variable oscillatory dynamics that characterises such systems.

Although we are witnessing rapid developments in the theory of nonautonomous and random dynamical systems, nonautonomous oscillatory systems with stable but time-varying characteristic frequencies have until recently not been considered. In this talk I will review the most recent work in the field and will discuss the newly introduced class of nonautonomous systems named chronotaxic (from *chronos* – time and *taxis* – order). Such systems are characterised by a time-dependent point attractor, and can maintain stable but time-varying amplitude and phase dynamics. I will introduce the cases of separable and non-separable amplitude and phase dynamics and will discuss methods for time-series analyses that are appropriate for capturing their features.

In the second part of my talk I will examine the biological cell as a chronotaxic system, paying particular attention to the role of adenosine triphosphate production in glycolysis and mitochondrial oxidative phosphorylation in oscillations of the membrane potential. At a higher level of complexity, I will approach the heart as a chronotaxic system. I will consider its interaction with the respiratory system and argue that ageing can be characterised by changes in the intensity of interaction between the two. The journey will end at the brain, with some recent results of brain dynamics, discussing how coupling functions between brain waves change in anaesthesia and in autistic spectrum disorder.

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On max-type difference equations

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Systems of difference equations of the following form

$$x_n^{(j)} = \max_{1\le i_j \le m_j} \left\{ f_{ji_j}\left(x^{(1)}_{n-k^{(j)}_{i_j,1}}, \dots, x^{(l)}_{n-k^{(j)}_{i_j,l}}, n \right) \right\}, \ \ n \in \mathbf{N}_0,$$

where $l, m_j, k^{(j)}_{i_j,h} \in \mathbf{N}$, $j,h \in \{1,\dots,l\}$, and $f_{ji_j} : \mathbf{R}^l \times \mathbf{N}_0 \to \mathbf{R}$, $j \in \{1,\dots,l\}$, $i_j \in \{1,\dots,m_j\}$, are called max-type systems. For $l = 1$ the system is reduced to a max-type difference equation. There has been some interest in such systems of difference equations in the last two decades. In this talk we present some recent results on the long-term behavior of solutions of some particular cases of the system.

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Microwave experiments in complex systems: From quantum chaos to monster waves

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Most of the phenomena observed in wave propagation are universal and are observed in a large variety of different systems such as matter waves, but also, e.g., in electromagnetic waves and water waves. By means of the microwave measuring technique pioneered in Marburg, it thus becomes possible to study questions extending from the quantum mechanics of chaotic systems to the propagation of waves in the ocean. In this talk recent microwave results are presented, including a microwave realization of graphene (Kuhl et al. 2010, Barkhofen et al. 2013a), the study of branched flow in potential landscapes (Höhmann et al. 2010, Barkhofen et al. 2013b), and the study of spectra and periodic orbits in microwave graphs (Allgaier et al. 2014).

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Many-body quantum theory beyond the semiclassics by quantum smoothing of singularity in quantum-classical correspondence

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A theory of many-dimensional real-time quantum dynamics is studied in terms of Action Decomposed Function (ADF), a class of wavefunction of the form

$$\Psi(\mathbf{q},t) = F(\mathbf{q},t)\exp\left(\frac{i}{\hbar}S(\mathbf{q},t)\right),$$

where $S(\mathbf{q},t)$ is assumed to satisfy the Hamilton-Jacobi equation at the outset, and a complex function $F(\mathbf{q},t)$ is thereby an unknown function to be studied [1]. It is shown that semiclassical dynamics for $F(\mathbf{q},t)$ in the Lagrange picture of phase-flow can be described with what we call deviation determinant and associated quantum phases without use of the stability matrix [2]. This talk is devoted to an analysis of the mechanism of quantum diffusion (quantum smoothing) that removes singularity inherent in semiclassics. We derive a Lorentzian form for the amplitude factor of $F(\mathbf{q},t)$ that is free of the semiclassical singularity, the real part of whose denominator comes from the deviation determinant, while the imaginary part reflects quantum diffusion and is proportional to the Planck constant ($\hbar$). Further, this imaginary part is shown to be attainable through a Wronskian relation with the deviation vectors. A number of theoretical advantages of the Loretzian form and the Wronskian relation are illustrated both theoretically and numerically. We will show that there is no essential difficulty in applications to many-dimensional heavy particle systems like molecules. We discuss the effects of the magnitude of $\hbar$ on the semiclassical quantization (of classical chaos [3]) in terms of the present $F(\mathbf{q},t)$ function, from which a new phase factor arises as a function of $\hbar$. We also discuss an interpretation of the quantum wavefunction.

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Unlearning abnormal neuronal synchrony by coordinated reset neuromodulation

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Several brain diseases are characterized by abnormal neuronal synchronization. To specifically counteract neuronal synchronization we have developed Coordinated Reset (CR) stimulation, a spatial-temporally patterned desynchronizing stimulation technique. According to computational studies CR stimulation induces a reduction of the rate of coincidences and, mediated by synaptic plasticity, an unlearning of abnormal synaptic connectivity. A sustained desynchronization is achieved by shifting the neuronal system from a pathological to a physiological attractor. Computationally it was shown that CR effectively works no matter whether it is delivered directly to the neurons somata or indirectly via excitatory or inhibitory synapses. Accordingly, CR stimulation can be realized by means of different invasive as well as non-invasive stimulation modalities. In accordance with theoretical predictions, electrical deep brain CR stimulation has pronounced therapeutic after-effects in Parkinsonian monkeys as well as cumulative and lasting therapeutic and desynchronizing after-effects in Parkinsonian patients. In tinnitus patients acoustic CR stimulation leads to a significant clinical improvement as well as a decrease of pathological neuronal synchrony in a tinnitus-related network of auditory and non-auditory brain areas along with a normalization of tinnitus characteristic abnormal interactions between different brain areas. In summary, the theory-based CR approach appears to be a promising novel therapeutic option for different brain dieseases.

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Time series analysis using wavelet to extract collective behavior of proteins

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We develop methods to extract collective behavior for time series data of molecular dynamics simulation of proteins. We use the wavelet transformation together with various tools such as the singular value decomposition (SVD) and the canonical correlation analysis (CCA). The wavelet analysis enables us to characterize non-stationary features of the dynamics. On the other hand, SVD enables us to reduce the degrees of freedom of the data, and CCA does to extract correlation among multiple groups of degrees of freedom. We apply our methods to time series data obtained by molecular dynamics simulation for *Thermomyces lanuginosa* lipase (TLL) and the PDZ domain.

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Quantum chaos in many-body quantum systems: interference, interactions and indistinguishability

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The field of *Quantum Chaos* studies the quantum effects that can be connected with the existence of classical chaos. During the past years, this connection provided a deep insight into a large variety of physical phenomena, from the emergence of universal spectral and transport fluctuations in the mesoscopic domain to the existence of dynamical localisation in driven quantum systems, passing from the role of classical chaos in the quantum-classical transition. The very root of this success is the possibility of using classical information to explicitly construct quantum mechanical objects that may not have themselves a well defined classical limit. The set of concepts and techniques that allows to follow this program is referred as the *semiclassical approximation*, and it is well justified when the classical actions are large.

In this presentation I will attempt to motivate our efforts to implement the semiclassical program in the framework of quantum systems of interacting, indistinguishable particles. In this scenario, the classical limit is a classical mean-field theory and it emerges in the limit of large total number of particles. After a general introduction to the semiclassical program in single-particle systems, showing the role of the classical limit in constructing quantum mechanical amplitudes (the celebrated van Vleck-Gutzwiller propagator), I will indicate how a similar object can be defined in the context of quantum fields. Then, I will show two applications of the semiclassical approach to bosonic systems: the prediction of many-body quantum interference in the dynamics of cold bosonic atoms in optical latices and the emergence of universality in the framework of the Boson Sampling problem.

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Automatic design of aerodynamic surfaces

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I will present methods for automatic optimisation of aerodynamic surfaces as developed at Pipistrel. These methods were used for the development of aerodynamics of the Taurus G4 aircraft, the winner of NASA 2011 Green Flight Challenge Sponsored by Google, as well as the four seat Panthera aircraft and the Eivie human powered vehicle. By a proper formulation of the optimisation criterion and parametrisation of surfaces, it is possible to design optimal wings, propellers, airfoils and fuselages, but also details such as wing root blending. I will mostly focus on two methods. The first method is used to find the optimal nonplanar shape of the wing (e.g. winglets), where it is demonstrated that there exists a critical point determining the optimality of the planar versus nonplanar configuration, depending on the parameter that determines the ratio between profile and induced drag. The second method uses an ideal fluid model and a pressure distribution based optimisation criterion. It is used to obtain three-dimensional shapes that result in laminar flow and prevent flow separation, and hence result in low drag.

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Abstracts of Short Reports

Statistical properties of 1D time-dependent Hamilton systems

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I shall discuss the general theory of parametrically kicked systems, especially in nonlinear 1D Hamiltonian systems. I shall present the general Papamikos-Robnik (PR) conjecture for parametrically kicked Hamilton systems, which says that for such systems the adiabatic invariant (the action) for an initial microcanonical ensemble at the mean final energy always increases under a parametric kick. I shall also present many examples of the validity of the PR property, which is almost always satisfied, but can be broken in not sufficiently smooth potentials or in cases where we are in the energy range close to a separatrix in the phase space. The general conjecture, using analytical and numerical computations, is shown to hold true for important systems like homogeneous power law potentials, pendulum, Kepler system, Morse potential, Pöschl-Teller I and II potentials, cosh potential, quadratic-linear potential, quadratic-quartic potential, while in three cases we demonstrate the absence of the PR property: Linear oscillator enclosed in a box, sextic potential, quartic double well potential. We shall discuss the physical relevance of these results.

In the second part of the talk I shall present the results of other kinds of time-dependent systems, namely the cases of almost adiabatic (almost infinitely slow) variation, the case of unlimited linear driving of homogeneous power law potentials, where the nonlinear WKB method developed by Papamikos and Robnik (2012) can be applied, and finally also the cases of periodic driving.

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A hopping model of the energy transport in time-dependent billiards

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The energy of a particle in a time-dependent billiard can grow without limit, and under certain conditions the energy growth can be even exponentially fast in time. Time-dependent billiards are important models in many physical phenomena, for example, they serve as a model of acceleration of cosmic particles which are colliding with moving interstellar magnetic domains, as originally proposed by Enrico Fermi. Thus it is important to understand what are the general conditions that imply the exponentially fast energy growth. I shall explain the origin of the exponentially fast acceleration introducing the hopping model of the particle dynamics, in which a trajectory of the particle is represented as a path through an abstract space of invariant components of corresponding static (frozen) billiards. Such paths, which I call ζ-trajectories, are generated probabilistically in terms of time-dependent Markov transition matrices. I will show that if the number of ζ-trajectories proliferate exponentially fast in time, then the average energy of an ensemble grows exponentially in time as well. This scenario takes place if the phase space of corresponding static billiards is of the mixed type - with coexisting chaotic and regular domains. I shall also discuss cases in which the acceleration is not exponentially fast but obeys the power law, and explain the associated acceleration exponents.

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Exactly Solvable Counting Statistics in Open Weakly Coupled Interacting Spin Systems

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We study the full counting statistics for interacting quantum many-body spin systems weakly coupled to the environment. In the leading order in the system-bath coupling we derive exact spin current statistics for a large class of parity symmetric spin-1/2 systems driven by a pair of Markovian baths with local coupling operators. Interestingly, in this class of systems the leading order current statistics are universal and do not depend on details of the Hamiltonian. Furthermore, in the specific case of symmetrically boundary driven anisotropic Heisenberg (XXZ) spin 1/2 chain we derive explicitly the third-order non-linear corrections to the current statistics.

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Degenerate Andronov-Hopf bifurcations in systems of ODE's

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In the first part of my talk I will discuss a Hopf (or Andronov-Hopf) bifurcation for planar systems. I will describe also limit cycles on the center manifold and degenerate Hopf (Bautin) bifurcations. In the second part of the talk I will present one of the most famous problems in qualitative theory of ordinary differential equations - Hilbert's sixteenth problem on the number of limit cycles of two dimensional polynomial systems

$$\dot{x} = P_n(x, y), \quad \dot{y} = Q_n(x, y)$$

(n is the maximum degree of the polynomials on the right-hand side of the system). An essential part of the problem is the problem of estimating of the maximum number of limit cycles which can bifurcate from a singular point of center or focus type under small perturbations of coefficients of the system, the so-called cyclicity problem. The key feature of our approach is that in the case of an elementary singular point the problem of cyclicity is reduced to the algebraic problem of searching for a basis of a certain polynomial ideal. We apply this approach for solving the cyclicity problem for a subfamily of cubic systems.

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Existence, dynamics and mobility of Quantum Compactons in an extended Bose-Hubbard model

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Lattice Compactons, discrete breathers with compact support, were found for a discrete nonlinear Schrödinger (DNLS) equation extended with nearest neighbour intersite nonlinearities [1], a model originally studied with waveguide arrays in mind. These compactons were shown to exhibit very good mobility if the parameters are tuned close to the compactons stability boundary. The DNLS can also be used to model the behaviour of Bose-Einstein condensates in optical lattices, and the remarkable control over the experiments in this field of research has made it possible to study the quantum mechanics of strongly correlated atoms.

We will define the concept of a Quantum Lattice Compacton [2] and discuss the existence and dynamics, with special emphasis on mobility [3], of these in an extended Bose-Hubbard model corresponding to above-mentioned extended DNLS equation in the quantum mechanical limit. The compactons is given 'a kick' by means of a phase-gradient and it is shown that the size of this phase is crucial for the mobility of the compactons. For small phase-gradients, corresponding to a slow coherent motion in the classical model, the time-scales of the quantum tunnelings become of the same order as the time-scale of the translational motion and the classical mobility is destroyed by quantum fluctuations. For large phase-gradients, corresponding to rapid classical motion, the classical and quantum time-scales separate so that a mobile, localized coherent quantum state can be translated many sites in the lattice already for small particle numbers of the order of 10 [3].

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On-off intermittency generated by infinite-modal maps

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On-off intermittency is an irregular switching phenomenon between long-term laminar behavior and instantaneous bursts. This phenomenon was discovered by Fujisaka and Yamada [1] in coupled chaotic systems, and observed in many experimental systems or mathematical models. Conventional mathematical models for on-off intermittency have been modeled using linear multiplicative noise systems. In such systems, it has been found that statistical properties such as the following are true at near the transition to transient behaviors from intermittent behaviors: (i) The stationary distribution about the distance r from the laminar state has $P(r) \sim r^{-1}$ $(r \ll 1)$ [2], (ii) The laminar duration distribution has $\rho(t) \sim t^{-3/2}$ $(t \gg 1)$ [3]. Since the above laws was observed from many experimental systems as well as mathematical models, they are regarded as the standard statistical laws for on-off intermittency.

Recently, in response to experimental examples deviating from such standard statistical laws, a probabilistic model which can change the exponents, such as -1 or $-3/2$, of the standard statistical laws by control parameters is devised [4]. However the deterministic model generating the non-standard statistical laws is not yet known. In such a situation, we found that the following one-dimensional dynamical system, which is an infinite-modal map, can generate on-off intermittency chaos:

$$x_{n+1} = x_n |x_n|^{a-1} \sin\left(b \log\left(1/|x_n|\right)\right), \quad -1 \le x_n \le 1. \tag{1}$$

where $a \in (0,1)$ and $b > 0$ are parameters. This map originates in the dynamics for near the homoclinic orbit of the saddle-focus point in ordinary differential equations [5,6]. In this presentation, we present that the essence for the dynamics of this map is a non-linear multiplicative noise system and that it has non-standard statistical laws, according to numerical simulations.

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Swarm Dynamics and Lyapunov Analysis

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The swarm dynamics is characterized by many local and global modes in the collective motions. The global response in the group dynamics is sensitively affected by the local aspects and also the local behaviors are controlled by the global information. The local-global linkage in the swarm dynamics is an essential mechanism, which leads to self-organization of the unified behavior in the swarm dynamics. In this paper, we consider a simple model to understand the linkage between local and global effects in the group dynamics by taking into account the local communicative interactions as well as the global environmental effects.

We propose the minimal model of active matters, where two parameters play the essential role in the group behavior: one is the environmental effect from the outside of the swarm, and the other is the communicative effect among individuals inside of swarm. The velocity of the i-matter is described by the following dynamics;

$$\dot{\mathbf{v}}_i(t) = \left(1 - |\mathbf{v}_i(t)|^2\right)\mathbf{v}_i(t) + \mathbf{F}^{comm}(t) + \mathbf{F}^{goal}(t) + \mathbf{F}^{env}(t) \tag{2}$$

For the sake of simplicity, the attractive effect of the goal information is shown by $\mathbf{F}^{goal}(t)$, the environmental effect from outside by $\mathbf{F}^{env}(t)$, and the communicative competence among individuals by $\mathbf{F}^{comm}(t)$. The first term is also a simplified form of the self-controlling effect to each velocity.

The Lyapunov exponents, which describe the sensitivity in the motion of each individual, is used to understand the global and local behaviors of the swarm dynamics. Increasing the size of the swarm, the exponents also increase. It will be discussed that the Lyapunov exponents (spectrum) affect the swarm dynamics of our model sensitively and the relation between the collective states and the instability. Detailed aspects of the Lyapunov exponents in the swarm dynamics are discussed in comparison with other chaotic dynamics of many-body systems.

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Anomalous transport processes of inertial Brownian particles induced by white Poissonian noise

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Absolute negative mobility (ANM) is counterintuitive phenomenon: particles move in a direction opposite to a static bias force. It seems to be in contradiction to the Newton equation motion, the second law of thermodynamics and observation of motion at a macroscopic scale. However, under non-equilibrium conditions, there is no fundamental principle which excludes ANM. What are essential ingredients for the occurrence of ANM? The minimal model can be formulated in terms of one-dimensional Newton equation for a Brownian particle moving in a symmetric spatially periodic potential, driven by unbiased harmonic force and biased by a static force F [1]. The ANM response in a symmetric periodic potential is so that an average particle velocity $\langle v(F) \rangle$ obeys the relation $\langle v(F) \rangle = -\langle v(-F) \rangle$, which follows from the symmetry arguments. In particular $\langle v(0) \rangle = 0$. So, for $F = 0$ there is no directed transport in the long time regime. The non-zero static force F breaks the symmetry and therefore induces a directed motion of particles. In the lecture, we replace the static force F by a random force $\eta(t)$ of a time-independent non-zero mean value $\langle \eta(t) \rangle = \eta_0$ [2]. We assume that the particle is coupled to its environment (thermostat) of temperature T and thermal fluctuations $\xi(t)$ are included as well. As an example of the random force $\eta(t)$, we consider non-equilibrium Poissonian white shot noise, which is composed of a random sequence of δ-shaped pulses with random amplitudes. We analyse the dependence of the long-time average velocity $\langle v \rangle$ on parameters of both random forces $\eta(t)$ and $\xi(t)$. We find a rich variety of anomalous transport regimes including the absolute negative mobility around zero biasing Poissonian noise, the emergence of a negative differential mobility and the occurrence of a negative nonlinear mobility (for values of bias η_0 far from zero). As a feasible physical system, we propound a setup consisting of a single resistively and capacitively shunted Josephson junction driven by both a time periodic current and a noisy current. In this case the phase difference between the macroscopic wave functions of the Cooper electrons in both sides of the junction translates to the Brownian particle coordinate and the voltage across the junction translates to the particle velocity. For such a system, the anomalous transport characteristics can be measured, thus putting our predictions to a reality check.

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Abstracts of Posters

Modelling ion channels with Brownian Dynamics

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Ion transport across cell membranes plays a fundamental role in human, animal and bacterial cells. Of the many computational methods used to investigate ion channels, Brownian Dynamics (BD) is of particular importance. This models ions in a water-filled charged protein using the over-damped Langevin equation due to the low Reynolds number of the ions. It is an electrostatic system and so, to ensure self-consistency the system must be coupled to the Poisson equation, which must be solved at fixed time steps to build a picture of each ions' trajectory.

The model (Kaufman et al 2013a) has proven successful at modelling the flow of ions in Ca^{2+} and Na^{+} channels and replicating key features such as selectivity and anomalous mole fraction effect (AMFE). It has been shown that Ca^{2+} and Na^{+} channels have distinct conduction and occupation bands as a function of the channel's charge. Further investigation of these bands has led to two important conclusions. First, consideration of the energetics in the system suggests that these bands correspond to a phenomenon known as barrier-less conduction (Berneche 2001, Yesylevskyy 2005). Secondly these bands can be thought of as ionic Coulomb Blockade (CB) analogous to electron CB as seen in a quantum dot. (Kaufman et al 2013a, Kaufman et al 2013b, Kaufman et al preprint)

Ion channels can be treated mesoscopically therefore exhibiting quantum-like features. These include, the aforementioned ionic CB, but also the use of the Fermi-Dirac distribution for occupation and the possibility of discussing ionic dynamics via a Schrödinger-like wave equation (Kamenev 2006). These features will be discussed.

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Layered architecture shapes context-dependent response and input integration of a cortical circuit

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Lamination is a landmark feature of cortical architecture. But even if functional specializations of individual layers have been suggested (Raizada and Grossberg 2003; Hirsch and Martinez 2006), the role played by interlayer connections in shaping the dynamical responses of a cortical column has not yet been fully elucidated.

Here, we analyze a mean-field model of a cortical column, embedding realistic interlayer connections (the one-column "connectome" of Binzegger et al. 2004). Systematically varying efficacy of excitation and inhibition in the model we find phase diagrams showing a great diversity of possible dynamical regimes. In particular, due to the presence of delayed inhibition, oscillations can be generated. Oscillations in different layers may be phase-locked or phase-precessing and have different frequencies. In some regions of the phase diagrams high frequencies (gamma-like) predominate in L23 while low beta-like frequencies predominate in L5. Remarkably, while this experimentally observed tendency is usually attributed to the different cortical sources to different layers, here it arises spontaneously in an isolated model column, resulting from the multilayer connectivity. The column is thus intrinsically predisposed to communication-through-coherence processes over multiple frequency bands. Furthermore, we find that horizontal or top-down currents, mediating perceptual context information, are non-linearly amplified and that vertical inter-layer interactions alone already contribute to contextual modulations of the column response, besides other interactions here not explicitly modeled. Our model predicts interlayer competition behaviors which could be probed experimentally by selective optogenetic (in)activation techniques. Finally, the robustness of our findings is discussed by comparison with alternative wiring diagrams.

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Chaotic behavior of R Scuti and R Leonis

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We shall present phase portrait reconstruction of two variable stars – R Scuti and R Leonis. The studied stars are at the end of their lifetimes (they burned all hydrogen in their cores). R Scu is RV Tauri type star, radially pulsating low mass supergiant; R Leo is a cool red giant (type Mira). Data for the analysis were obtained from the AAVSO database. Phase portraits were reconstructed using the method of time delayed coordinates. Proper time delays and the embedding dimensions were estimated from the first minimum of mutual information. From computed maximum Lyapunov exponent and correlation dimension was proven that R Scu star exhibits chaotic behavior and thus we confirmed results made by Buchler et al., who were using different method. In the case of R Leo star results are quite uncertain and we still cannot confirm underlying low-dimensional dynamics. We also found that noise can have a big influence on the results so we have to be carefull about choosing the right method for noise reduction. The TISEAN package was used for processing all the data.

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Can single cancer cell behaviour be related to local blood flow dynamics?

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Motivated by recent results in which the microvasculature local to malignant melanoma was found to exhibit reduced vasomotion when compared to that in healthy skin and atypical naevi [1], we seek to understand these results through the development of a cellular model of cancer, based on alterations to oscillations which are known to be present in healthy cells.

Previous studies have found oscillations in metabolism, both in the mitochondria [2] and during glycolysis [3], and one of their most crucial products, ATP. These oscillations in ATP have been related to oscillations in the cell membrane potential. Cancer cells are known to have suppressed mitochondria, possibly to prevent apoptosis, and upregulated glycolysis, to enhance survival probability during periods of hypoxia. Another universal feature of cancer cells is the depolarization of their cell membrane potential [4], which may be related to their being constantly in a state of proliferation.

We hypothesize that modelling the cell membrane potential of a cancer cell in terms of coupled cellular oscillators, and allowing for time-varying but stable frequencies using the recently developed class of non-autonomous systems known as chronotaxic systems [5, 6, 7], will allow us to link the behaviour of a single cancer cell to the macroscopic changes in blood flow observed in reality.

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Supply Networks: Instabilities without Overload

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Supply and transport networks support many biological processes and much of our technical infrastructure. Their reliable function is thus essential for all aspects of life. Transport processes involving quantities beyond the pure loads exhibit alternative collective dynamical behaviour compared to processes exclusively characterized by loads. Here we report that oscillator models describing electric power grids can exhibit instabilities even if there is no overload.

We first characterize the fixed points (normal operation of the grid) in the limit of zero dissipation in terms of Hamiltonian dynamics. In systems with dissipation, all fixed points are identical to local extrema/saddle points of the (Hamiltonian) potential, which depends on the network topology. We classify spectral and asymptotic stability properties of fixed points and provide an elementary example. We show using graph theoretic tools that if the phase difference along each transmission line $|\theta_j - \theta_i|$ is not more than $\frac{\pi}{2}$, then instability is always caused by an overload on one or more lines. However, if one or more lines have phase difference exceeding $\frac{\pi}{2}$, we demonstrate that a fixed point can lose stability even though no line is overloaded. This phenomenon may also emerge in other sufficiently complex supply or transport networks.

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Mathematical modeling of intracellular Ca^{2+} and membrane potential dynamics in the beta cell syncytium

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Pancreatic beta cells in the islets of Langerhans regulate whole body nutrient homeostasis by secreting the hormone insulin in a regulated manner. Glucose stimulation elicits depolarization of the cell membrane by decreasing the open probability of ATP sensitive K^+ ion channels, which results in electrical activity of beta cells in terms of Ca^{2+} entry and action potential firing. Ca^{2+} subsequently acts on the exocytotic machinery to stimulate fusion of insulin-containing vesicles with the plasma membrane for secretion into the bloodstream [MacDonald & Rorsman, 2006]. The bulk of evidence indicates that the Ca^{2+}, electrical and secretory responses of beta cells to glucose are not only properties of individual cells but also crucially rely on collective activity of cell populations [Rutter & Hodson, 2013]. However, the precise mechanisms of the nature and extent of coupling within the syncytium are poorly understood. A thorough understanding of all these complex molecular, cellular and intercellular mechanisms that govern the functioning of islets, requires the support of mathematical modeling of physiological data. Existing models for beta cells are generally based on the Hodgkin-Huxley equations for neuronal electrical activity, although many efforts have been made to incorporate cell-specific details as well as different aspects of intercellular communication [Hraha *et al.*, 2014]. Despite the fact that many of the established computational models fit well the various aspects of intra- and inter-cellular dynamics observed in previous experiments, they fail to firmly describe our novel and most recent experimental results obtained by means of in situ acute mouse pancreas tissue slice preparation with noninvasive fluorescent calcium and voltage labeling and the subsequent confocal laser scanning microscopy [Stožer *et al.*, 2013, Dolenšek *et al.*, 2013]. In order to address this issue we upgrade the existing modeling approaches and develop a detailed model of interconnected beta cells, which incorporates additional physiological specifics and leads to a better agreement between our experimental findings and theoretical predictions. Our results exemplify that a combination of modern high spatial and temporal resolution confocal imaging and computational modeling is a powerful approach that leads to a comprehensive understanding of the islet topology and its function.

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Probing the role of accelerator modes on the dynamical localization properties of the quantum kicked rotator and on the anomalous diffusion of its classical analogue

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We study the N-dimensional model of the quantum kicked rotator in the classically fully chaotic regime, which in the limit of sufficiently large N tends to the quantized kicked rotator. We describe the features of dynamical localization of chaotic eigenstates as a paradigm for other both time-periodic and time-independent (autonomous) fully chaotic or/and mixed type Hamilton systems. We generalize the scaling variable to the case of anomalous diffusion in the classical phase space, by deriving the localization length for the case of generalized classical diffusion. We then focus on the effect of the anomalous diffusion arising due to the accelerator modes in the classical kicked rotator, exemplified by the standard map. The systematic approach rests upon detecting the regular and chaotic regions and thus to describe in detail the structure of the phase space, the description of the momentum distribution in terms of the Lévy stable distributions, the numerical calculation of the diffusion exponent and of the corresponding diffusion constant. We use this approach to analyze in detail and systematically the standard map at all values of the kick parameter K, up to $K = 70$. All complex features of the anomalous diffusion are well understood in terms of the role of the accelerator modes, mainly of period 1 at large $K \geq 2\pi$, but also of higher periods (2,3,4,...) at smaller values of $K \leq 2\pi$.

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MATHEMATICAL MODELING OF PLANAR CELL POLARITY IN EPITHELIAL TISSUES DURING DEVELOPMENT

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Abstract

The polarization of epithelial cells in the plane of a tissue is referred to as planar cell polarity (PCP) and is of crucial importance for the normal development of specialized biological structures and hence a biological organism as a whole. The term polarity in PCP is related to the asymmetric distribution of core PCP proteins involved in the intra-cellular signaling pathway [1]. Experimental studies performed on the wings of the Drosophilia fly have shown that PCP of individual cells is established through the interplay between intra- and inter-cellular communication accompanied by a global cue. Although most of the existing knowledge on PCP is based on experimental studies done on fly wings, the same mechanism have been found to govern the establishment of PCP in vertebrates [2]. Faults in PCP signaling caused by mutations in the intra-cellular signalization lead to impaired polarity patterns of the epithelium layer, which can result in serious pathological conditions [3]. Computational modelling have proven to be a very reliable approach for studying the complex processes involved in PCP. The strategy of in silico experiments enables a precise tracking of the behavior and spatial arrangement in case of different dysfunctions in intra-cellular signaling. In our previous study [4], we constructed a mathematical model of the epithelium mono-layer as a 2D hexagonal grid, where each hexagon in the lattice represents an epithelial cell. The modeling of the orientation and magnitude of polarization of individual cells and the intercellular interactions is based on the theoretical framework introduced by *Hazelwood&Hancock* [5]. The model includes only physically relevant terms that account for the cells ability to maintain its own intracellular polarisation, interact with the polarity of adjoining cells and interact with a global field, which are described by a free energy function. The stationary polarity patterns are acquired by numerically integrating the free energy function and finding its global minima. Here we extend our previous studies to non-uniform cell shapes and consequently a varying number of neighbouring cells. The increased heterogeneity in the shape of the cells is also implemented in the free energy function by weighting inter-cellular interactions in accordance with the length of tight junctions between two cells. We investigate the role of cells with impaired intracellular signalling, i.e. mutant cells, on the global pattern formation. For the characterization of the polarized cytoarchitectures we use the local and global order parameters. We additionally analyse the possible scenarios of PCP establishment during development, with emphasis on the impact of mutant cells on the overall organization in the global polarity pattern.

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On-off intermittency generated by infinite-modal maps

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On-off intermittency is an irregular switching phenomenon between long-term laminar behavior and instantaneous bursts. This phenomenon was discovered by Fujisaka and Yamada [1] in coupled chaotic systems, and observed in many experimental systems or mathematical models. Conventional mathematical models for on-off intermittency have been modeled using linear multiplicative noise systems. In such systems, it has been found that statistical properties such as the following are true at near the transition to transient behaviors from intermittent behaviors: (i) The stationary distribution about the distance r from the laminar state has $P(r) \sim r^{-1}$ ($r \ll 1$) [2], (ii) The laminar duration distribution has $\rho(t) \sim t^{-3/2}$ ($t \gg 1$) [3]. Since the above laws was observed from many experimental systems as well as mathematical models, they are regarded as the standard statistical laws for on-off intermittency.

Recently, in response to experimental examples deviating from such standard statistical laws, a probabilistic model which can change the exponents, such as -1 or $-3/2$, of the standard statistical laws by control parameters is devised [4]. However the deterministic model generating the non-standard statistical laws is not yet known. In such a situation, we found that the following one-dimensional dynamical system, which is an infinite-modal map, can generate on-off intermittency chaos:

$$x_{n+1} = x_n |x_n|^{a-1} \sin\left(b \log\left(1/|x_n|\right)\right), \quad -1 \le x_n \le 1. \tag{3}$$

where $a \in (0,1)$ and $b > 0$ are parameters. This map originates in the dynamics for near the homoclinic orbit of the saddle-focus point in ordinary differential equations [5,6]. In this presentation, we present that the essence for the dynamics of this map is a non-linear multiplicative noise system and that it has non-standard statistical laws, according to numerical simulations.

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THE GRAVITATIONAL BILLIARD

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This paper concerns the motion of a point particle moving in a symmetric wedge of angle 2α subject to a constant gravitational field of magnitude g, pointing downward along the direction of the axis of symmetry. All collisions are assumed to be elastic, thus total mechanical energy is conserved. This system is a rather simple one, that shows a remarkable complex behavior in spite of its two degrees of freedom. Since its main properties are already known (e.g. KAM regions, Lyapunov exponents etc.), the aim of this paper is to show a different way to approach the problem, using cartesian coordinates instead of polar. The region of integrability ($\alpha = 45°$) will be the one of main interest; a new constant of motion at $\alpha = 45°$ will be found and used as a tool to observe a chaotic attractor-like behavior just outside the region of integrability.

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Swarm Dynamics and Lyapunov Analysis

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The swarm dynamics is characterized by many local and global modes in the collective motions. The global response in the group dynamics is sensitively affected by the local aspects and also the local behaviors are controlled by the global information. The local-global linkage in the swarm dynamics is an essential mechanism, which leads to self-organization of the unified behavior in the swarm dynamics. In this paper, we consider a simple model to understand the linkage between local and global effects in the group dynamics by taking into account the local communicative interactions as well as the global environmental effects.

We propose the minimal model of active matters, where two parameters play the essential role in the group behavior: one is the environmental effect from the outside of the swarm, and the other is the communicative effect among individuals inside of swarm. The velocity of the i-matter is described by the following dynamics;

$$\dot{\mathbf{v}}_i(t) = \left(1 - |\mathbf{v}_i(t)|^2\right) \mathbf{v}_i(t) + \mathbf{F}^{comm}(t) + \mathbf{F}^{goal}(t) + \mathbf{F}^{env}(t) \tag{4}$$

For the sake of simplicity, the attractive effect of the goal information is shown by $\mathbf{F}^{goal}(t)$, the environmental effect from outside by $\mathbf{F}^{env}(t)$, and the communicative competence among individuals by $\mathbf{F}^{comm}(t)$. The first term is also a simplified form of the self-controlling effect to each velocity.

The Lyapunov exponents, which describe the sensitivity in the motion of each individual, is used to understand the global and local behaviors of the swarm dynamics. Increasing the size of the swarm, the exponents also increase. It will be discussed that the Lyapunov exponents (spectrum) affect the swarm dynamics of our model sensitively and the relation between the collective states and the instability. Detailed aspects of the Lyapunov exponents in the swarm dynamics are discussed in comparison with other chaotic dynamics of many-body systems.

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THE STUDY OF HURST EXPONENT OF KEPLER CONTACT BINARIES

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We have measured the Hurst Exponent (HE) of 19 (up to now) Center Between Maxima (CBM) O-C diagrams of contact binaries observed with the Kepler space telescope, developed for following the migration of star spots with high precision. All of the HEs are significantly greater than 0.5, indicating a persistent behavior. One of the binaries (KIC 6057829) posseses an HE close to unity, implying strict periodicity underlying the fluctuating migration, confirmed by the Lomb-Scargle periodogram. The correlation between HE and orbital period shows that high HE (¿0.9) binaries tend to gather around a typical contact binary period (0.37 day). The correlation between HE and the spot activity period shows a considerably uniform distribution among all HE values. The ongoing research may provide significant insight in the spot migration dynamics in the near future.

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CHARACTERIZING COUPLING FUNCTIONS IN NETWORKS OF OSCILLATORS

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Networks can be found everywhere in nature: from large-scale climatic interactions, to medium-scale synchronously firing ensembles of neurons in the brain, to small-scale coupled molecular systems. How to characterize and reconstruct networks from data is therefore a challenge which pervades all of science.

Numerous methods that detect the existence of causal connections in networks have already been introduced. However, they are mainly focused to pairwise interactions.

Here we present a new method, based on dynamic Bayesian inference which is capable to detecting effective phase connectivity between networks of time-evolving coupled oscillators subject to noise.

As we will see, it can reconstruct not only pairwise, but also joint and higher degree conductivities, including triplets and quadruplets of interacting oscillators.

Moreover, one can infer details of coupling functions from which the existence of causal links can be determined as well as the underlying functional mechanisms.

We will illustrate the characteristics and potentials of the method using an example of numerically generated network of phase oscillators with time-dependent coupling parameters and subject to noise. Furthermore, results from real data with extracted coupling functions between EEG brain waves will be shown.

The coupling functions of the pairwise $\delta - \alpha$ interactions and the triplet $\theta - \alpha - \gamma$, including their functional forms, will be presented in detail. Based on multi-channel recordings, spatial connectivity between these brain waves will also be revealed, thus illustrating the great potentials of our new method for reconstructing properties of networks of interacting oscillators in general.

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Stankovski T, Ticcinelli V and Stefanovska A 2014 *To be published*

Concerts

CONCERT

FLUTE QUARTET OF GRAZER SALONORCHESTER

Zivile Pirkwieser - flute **Barbara Upelj** - violin **Emilia Gladnishka** - viola **Olena Mischii** - cello

Kavarna Art, Hotel PIRAMIDA

Monday, 23 June 2014, 19:00

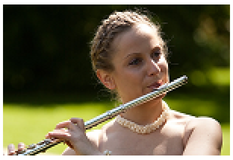
Program

- **G. F. Händel** CHACONNE IN G MAJOR
- **S. Rachmaninoff** STRING QUARTET No. 1 Romance Scherzo
- **F. Kreisler** LIEBESLEID
- **P. de Sarasate** ROMANZA ANDALUZA
- **M. McLean** DANCES FOR STRING QUARTET
- **Traditional** LA BAMBA

Arrangements made by Matthew Naughtin and Flute quartet of Grazer Salonorchester

Flute Quartet of Grazer Salonorchester was formed in 2011, but it works in this particular cast from March 2014. The formation derives from classical string quartet, however it gets an unique sound by substituting one violin with flute. The FQGS performs original pieces, arrangements of classical and popular music and pieces written especially for them. This is a chamber group that is definitely worth hearing.

All four musicians are members of Grazer Salonorchester, a leading Graz music society for promotion and development of chamber music. They are all experienced musicians whose love for chamber music has brought them together in a very unique and interesting way.



Mag. Zivile Pirkwieser was born in Kaunas, Lithuania. She graduated with honors at the University of Music and Performing Arts in Graz, where she studied flute with Professor Nils-Thilo Krmer. She is a flutist and a coordinator for Grazer Salonorchester. As a concert flutist she had concerts in Japan, Taiwan, Germany, France, Lithuania and Kazakhstan. Zivile is also an enthusiastic teacher, she teaches flute at Judenburg and Mariazell Music Schools.

Barbara Upelj, M. M. was born in Maribor, Slovenia. She graduated from Academy of Music in Ljubljana in 2006, where she studied with professor Rok klopčič. In 2006 she was accepted to a postgraduate program at The University of Texas at Austin, Texas, where she studied with Dr. Eugene Gratovich. She completed her studies with honors in May 2008. She performed at music festivals in Europe (Saint Petersburg, Russia; Burgos, Spain; Viana do Castelo, Portugal) and the USA (Austin, Texas), In 2008 she was honored by the University of Texas at Austin for an outstanding master's recital. She was one of the first members of Austin Pops, the leading Austin orchestra for popular music. During her time at the UT at Austin she was a member of String Project, an organization for educating children in string instruments and Dr. Eugene Gratovich's teaching assistant. In summer of 2009 she organized the festival Glasba v Kloštru in Ptuj, which had a great response and has been an important part of Ptuj's cultural life ever since. She is a co-founder of Duo Fla- her musical engagements also include Terrafolk, rock group Avven, the A la Fetish project and many other classical and non-classical projects. She continues her studies in the field of musical pedagogy at Edgar Willems Center in Ljubljana. Currently she is active as a solo and chamber musician in Graz, Austria and is a member of Grazer Salonorchester.

Emilia Gladnishka was born in Sofia, Bolgaria. She graduated with honors in 2001 at the Nationa Music Academy in Sofia, Bulgaria, where she studied with Professors Stefan Jilkov (viola) and Dimitar Kozev (chamber music). In 2009 she finished her masters studies at The University of Music and Performing Arts in Graz, where she studied viola performance with Professor Christian Euler. Emilia attended many national international music competitions and festivals in Austria and Bolgaria. She was a solo violist in Maribor Philharmonic Orchestra between 2004 and 2007 and is currently employed as a violist in Graz Philharmonic Orchestra. She is also active as a chamber musician and is a member of Grazer Salonorchester.

Olena Mischii was born in Kiev, Ukraine. She graduated from Tchaikovsky National Music Academy in Kiev, Ukraine in 2008, where she studied cello with Professor I. J. Kucher and piano with Professor M. J. Severinova. In 2012 she finished her bachelor degree at The University of Music and Performing Arts in Graz, where she studied with professor Kerstin Feltz. Olena attended several national and international competitions in Ukraine and Slovakia. As a cellist she worked with National Radio Orchestra in Kiev, TNMA Professional Orchestra and National Opera Orchestra in Kiev, Ukraine. From 2007 she lives in Graz, Austria, where she is works as a solo and chamber musician as well as a cello teacher. She is a member of several chamber groups and Grazer Salonorchester.

CONCERT

Nejc Kamplet

Kavarna Art, Hotel PIRAMIDA

Satudray, 28 June 2014, 19:00

Program

1. **J. S. Bach (1685-1750)** Prelude and fugue in E flat BWV 876
2. **Joseph Haydn (1732-1809)** Sonata in D major Hob XVI: 33
   - 1st movement, allegro
3. **S. Rachmaninoff (1873-1943)** Etude Tableaux Op. 39, No. 9 in D major
4. **Alojz Srebotnjak (1931-2010)** Macedonian Dances
5. **Ludwig van Beethoven (1770-1827)** Sonata No. 21 in C major, Op. 53, Waldstein
   - allegro con brio
   - adagio molto
   - rondo, allegretto moderato - prestissimo
6. **Robert Kamplet (1971)** Meditation
7. **Frederic Chopin (1810-1849)** "Heroic" Polonaise Op. 53 in A flat major

Nejc Kamplet, coming from Slovenia is son of the composer and the flautists and is learning the piano since the age of five. He graduated from music in the Conservatory in Maribor with Distinction (class of Saša G. Donaldson). He is now a student of a high school in Maribor (Slovenia) and at the same time he is studying at the University of Music and performing Arts Graz (Kunstuniversität Graz, Austria) in the class of Dr. Zuzana Niederdorfer. He has received many awards and first places at the national and international competitions. The major awards during the recent time are: golden plaques and special awards for the best performances of pieces by Slovenian composers in national competition TEMSIG in the years 2007, 2010 and 2013, first prize at the international competition Zlatko Grgoševič in Zagreb, Croatia (2008), first prize and special prize for the best performance of classical sonatas at the competition of Ars Nova in Trieste (2008) and WPW Panmusica in Vienna (2009) (second prize). In the year 2013 he won the first prize (absolute points) in competition T. Holmar in Malborghetto (Italy) and second prize at the piano competition Giovanni Musicisti in Trevisio (Italy). He also played in the Infinitum piano trio who won the first prize at the national competition TEMSIG (2011) for chamber music. Nejc Kamplet regularly attends master classes in Slovenia, Germany, Croatia, Liechtenstein, Estonia, Slovakia, etc. He is participating in many music festivals in Slovenia (Festival Lent, Festival Maribor, etc.) and he also played many piano concertos with many orchestras. Most noticeable are: Mozart Concertos K41, K482, K365(2007, 2010, 2011), Beethoven first Piano Concerto in C major (2012), E. Grieg first Piano Concerto in a minor (2013) and in January 2014 he played his father's R. Kamplet first piano concerto with SNG (Maribor symphony Orchestra) with conductor Tae Jung Lee. He also participated with many other renowned conductors (Benjamin Pionnier, Slavko Magdič, Živa P. Peršuh, etc.). In 2010 he received the prize Dr. R. Klasinc by the Conservatory of Music and Ballet Maribor for the best students.

CONCERT

Urška Orešič - piano vocal
Doris Šegula - violin

Jazz standard concert

Kavarna Art, Hotel PIRAMIDA

Tuesday, 1 July 2014, 19:00

Program

1. Kosma/Mercer: AUTUMN LEAVES
2. U. Orešič Š/F. Lainšček: MOJ LJUBI
3. A.J.Lerner/F. Loewe: WOULDN'T IT BE LOVERLY
4. H. Mancini: MOON RIVER
5. B. Howard: FLY ME TO THE MOON
6. R. Rodgers/L. Hart: MY FUNNY VALENTINE
7. Andre,Schwandt/Kahn: DREAM A LITTLE DREAM OF ME
8. G.& I. Gershwin: SUMMERTIME
9. H. Mancini: PINK PANTHER
10. L. Casucci/Frati, Brammer: JUST A JIGOLO
11. G. Shearing/Weiss: LULLABY OF BIRDLAND
12. H. David & B. Bacharach: RAINDROPS KEEP FALLING ON MY HEAD
13. Jobim/Gimbel: BOY FROM IPANEMA

Urška Orešič (born 1981 in Maribor) in 2005 graduated with honors from the study of composition and music theory at the Academy of Music (supervisor prof. Mihelčič Pavel) in 2009 from the piano (supervisor prof. Andrej Jarc), and in 2011 completed her postgraduate Masters studies in composition. At the time she was Zois scholarship, she presented her chamber music by the two authors' evenings and in 2005 won the Student's Prešeren Prize. The Music Opus includes different soloist, choral, chamber and orchestral works. Among the most important works are considered: more songs and songs for voice in various formats ("Toast to Old Vine", "Lost faith" ...), adaptations of Slovenian folk songs ("I'm a young girl, happy", "Flowers" ...), "Vitis Vinifera" - program music of the Vine, "Triton" for orchestra, "Flinstone from the Sun" for male octet, more musical songs to texts by Feri Lainšček ("Demons", "Aphrodite", "Bicycle" ...), etc.. Urska Oresic operates as an independent musical artist: composer, pianist, accompanist and singer of various genres of music and collaborates with renowned Slovenian musicians. She works as a solfeggio and harmony professor at Gymnasium of Art in Celje.

Doris Šegula, violinist, born 1988 in Celje, Slovenia. Is in the moment finishing her master study PPCM (Performance Practice in Contemporary Music) under the lead of the ensemble Klangforum Wien at University for Music and Performing Arts Graz (Austria). Finished her Bachelor Degree on the same University in 2011- IGP, violin classic, class Anke Schittenhelm. She is regulary performing as a solist and in different chamber groups in Slovenia and abroad, playing diverse styles (tango project Arstango with accordeonist Marko Hatlak, jazz in duo *New Paris* with doublebassist Luka Herman Gaiser, improvisation with guitar player Samo Ismajlovič and percussionist Bojan Krhlanko). Played in different slovenian and foreign orchestras, such as Slovenian Philharmonic Orchestra, Simfonic Orcherstra of Slovenian National Theater Maribor, String orchestra Celje (Slovenia), String orchestra Capella Callioppe (Graz), and other project or summer festival orchestras, ensembles (*Neofonia* with conductor Steven Loy, International symphonic Orchestra *Die Preisträger* - Switzerland).

CONCERT

STRING QUARTET FEGUŠ

Kavarna Art, Hotel PIRAMIDA

Wednesday, 2 July 2011, 19:00

Program

J.S. Bach: *"Die Kunst der Fuge" BWV 1080:* selected counterpoints for string quartet

M. Mihevc: String Quartet

P.I. Čajkovski: String Quartet in d-minor, op.11

"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.

CAMTP

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