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CAMTP

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**”Let’s Face Chaos  
through  
Nonlinear  
Dynamics”**

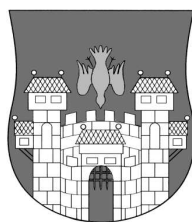
**9th International  
Summer School/Conference**



**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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# CAMTP

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**Center for Applied Mathematics and Theoretical Physics**

**Univerza v Mariboru • University of Maribor**

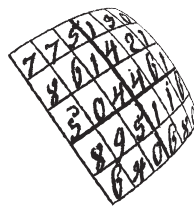
**Krekova 2 • SI-2000 Maribor • Slovenia**

**Phone +(386) (2) 2355 350 and 2355 351 • Fax +(386) (2) 2355 360**

**e-mail [Robnik@uni-mb.si](mailto:Robnik@uni-mb.si) • <http://www.camtp.uni-mb.si>**

**Director: Prof.Dr. Marko Robnik, Member of EASA**

**funded by ARRS - The Slovenian Research Agency**



SLOVENIAN RESEARCH AGENCY

**organizes**

The 9th International Summer School/Conference

**”Let’s Face Chaos through Nonlinear Dynamics”**

University of Maribor, Maribor, Slovenia

22 June - 6 July 2014

e-mail [chaos@uni-mb.si](mailto:chaos@uni-mb.si) • <http://www.uni-mb.si/chaos/2014/>

**under the patronage of the**

**European Academy of Sciences and Arts (Salzburg)**



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## THE ORGANIZING COMMITTEE

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**Marko Robnik** (CAMTP, Maribor, Slovenia)

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**Giulio Casati** (Como, Italy)

**Predrag Cvitanović** (Atlanta, USA)

**Theo Geisel** (Göttingen, Germany)

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**Andreas Ruffing** (Munich, Germany)

**Aneta Stefanovska** (Lancaster, England, UK)

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Japan

**Professor Dr. Stefano Boccaletti**

Institute for Complex Systems, Firenze  
Italy

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University of Patras  
Greece

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University of Vienna  
Austria

**Professor Dr. Sergej Flach**

Massey University, Auckland  
New Zealand

**Professor Dr. Theo Geisel**

Max-Planck-Institute for Dynamics and  
Self-Organization and Physics Department,  
University of Göttingen  
Germany

**Professor Dr. Thomas Gilbert**

Université Libre de Bruxelles  
Belgium

**Professor Dr. Siegfried Großmann**

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Germany

**Professor Dr. Fritz Haake**

University of Essen-Duisburg,  
Germany

**Professor Dr. Takahisa Harayama**

Waseda University, Tokyo  
Japan

**Professor Dr. Maxim S. Krass**

Institute of Macroeconomic Research, Moscow  
Russia, t.b.c.

**Professor Dr. Marko Marhl**

Faculty of Education & Faculty of Natural  
Sciences and Mathematics, and CAMTP,  
University of Maribor  
Slovenia

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and  
University of Nova Gorica  
Slovenia

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University of Tokyo  
Japan

**Professor Dr. Peter Tass**

Research Center Jülich  
Germany

**Professor Dr. Mikito Toda**

Nara Women's University  
Japan

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# THE SCIENTIFIC PROGRAMME

## INTRODUCTION AND THEORETICAL BACKGROUND

Synergetic approach to self-organizing systems  
Discrete versus continuous representation of dynamical systems  
Mathematical background  
Physical background  
Classical and quantum Hamiltonian systems  
Dissipative systems  
Ergodic theory  
Open systems  
Information dynamics  
Fractal structures - geometry of chaos  
Quantum aspects of classical chaotic systems (quantum chaos)  
Qualitative and quantitative analysis of time series  
Modelling and simulation of system dynamics  
Qualitative modelling - problems and perspectives

## SCIENTIFIC DISCIPLINES

### **Physics and Mathematics**

Classical Hamiltonian nonlinear dynamics  
Chaos in celestial mechanics and stellar dynamics  
Chaos in the Solar System dynamics  
Dynamics of dissipative systems  
Fluid dynamics: Theory of turbulence  
Cellular automata  
Quantum physics: Quantum chaos  
Atomic and molecular physics  
Semiclassical mechanics  
Periodic orbit theory (Gutzwiller approach)  
Random matrix theories  
Mesoscopic systems (microstructures, quantum dots)  
Microwave cavities and wave chaos

**Engineering**

Structural and dynamical stability  
Control of chaos in mechanical systems  
Electrical circuits  
Neural networks and neural computers  
Chemical reactions  
Mesoscopic solid state systems

**Biophysics and Physiology**

EEG  
Brain functioning  
ECG  
Blood flow (revealing oscillators)  
Modelling of complex biological and physiological systems  
Turing structures  
Pattern formation

**Economy**

Econophysics  
Evolutionary economics, macroeconomic cycles  
Stock market dynamics  
Financial systems  
Sociological aspects of economical structures and developments

## FOREWORD, SOME HISTORY AND PURPOSE

Chaos, either classical or quantum, conservative or dissipative, pure or applied, has become a fashionable subject of pronounced activities of nonlinear science during the recent decades. It is attracting the attention of not merely scientists in the relevant and related multidisciplinary and interdisciplinary scientific fields but even of philosophers or writers, coming up in daily papers and popular magazines. It often gives rise to turbulent controversies and disputes concerning its scientific merit and its practical use. Today, this field of research is very well established, it is immensely important in both pure science and in technology, and in fact might be considered as one of the scientific revolutions of 20th Century, extending its fast development into the 21st Century. It has a great and very important future for many centuries to come. In broader sense, it simply encompasses the totality of complex systems in nature, technology and society. This summer school and conference will put a great emphasis on the physics of complex systems, including the socio-economic sciences and the future information and communication technologies.

In August 1992, a group of students at the University of Ljubljana, led by the initiator Mrs. Maja Malus, came up with the idea to organize a summer school covering the variety of topics in pure and applied research on chaos. The main organizational effort was undertaken by the voluntary student staff under the direction of Maja Malus, then undergraduate student of electrical engineering at the University of Ljubljana and with active support of the international student association IAESTE. The scientific advisory board of the School (Professors Igor Grabec, Marko Robnik and Aneta Stefanovska) set up in March 1993, enjoyed the enthusiasm of the students, their devotion and hard work which eventually resulted in a very successful meeting. Financial support of many Slovenian sponsoring and donating companies and institutions, especially IBM Slovenia and the Ministry of Science and Technology, was highly appreciated and acknowledged. The hard and enthusiastic work of the student staff, the technical organizer of the School, was crowned with the prestigious charter and the golden tablet of the University of Ljubljana, for the "*...exceptional achievements in organizing the International Summer School...*".

The Summer School has become a tradition now: The second School was held at the University of Ljubljana in August 1994 (one week), and the third one on 24 June - 5 July 1996 at the University of Maribor, as a part of the activities of CAMTP. The 4th School/Conference held at CAMTP, University of Maribor, on 27 June - 11 July 1999 was again very successful indeed, for we had 37 invited lecturers from all over the world, from all continents, and in total about 105 participants. The fifth School/Conference, held traditionally at CAMTP on 30 June - 14 July 2002, was even stronger, as we had 40 invited lecturers and speakers from all over the world, and altogether about 130 participants. This tradition continues.

All Schools were strongly international, in the sense that about 90% of all participants (lecturers and "students") were from abroad. The lecturers, about twelve in 1993 and 1994, and about 27 in 1996, 37 in 1999, 40 in 2002, 46 in 2005, 46 in 2008, 48 in 2011, were from among the leading scientists in the relevant scientific disciplines, from many countries worldwide, including USA, Canada, Russia, Japan, Western and Eastern Europe, Israel, Australia, Mexico, Argentina, Brazil, China and/with Hong Kong, etc. The School was intellectually dignified by the attendance and the lectures of such distinguished scientific scholars as Professor Boris Chirikov from Novosibirsk, Russia, Professor Siegfried Großmann from Marburg, Germany, Professor Giulio Casati from Como, Italy, Professor Erik Mosekilde from Lyngby, Denmark, Professor Uzy Smilansky from Rehovot, Israel, Professor Hermann Haken from Stuttgart, Germany, Professor Predrag Cvitanović from Atlanta, Professor Oriol Bohigas from Orsay, France, Professor Giovanni Gallavotti from Rome, Italy, Professor George Contopoulos from Athens, Greece, Professor Yoshiki Kuramoto, Kyoto,



Japan, Professor Yoji Aizawa from Tokyo, Japan, Professor Tassos Bountis from Patras, Greece, Professor Theo Geisel from Göttingen, Germany, Professor Pierre Gaspard from Brussels, Belgium, Professor Hans A. Weidenmüller from Heidelberg, Germany, and many others.

It should be mentioned that since 2002 we have the tradition that the Summer School & Conference is dedicated to some prominent physicist, namely: Hermann Haken in 2002 on occasion of his 75th birthday, Siegfried Grossmann in 2005 on occasion of his 75th birthday, Giulio Casati in 2008 on occasion of his 65th birthday and Predrag Cvitanović in 2011 on occasion of his 65th birthday. This year, in 2014, it is dedicated to Professor Theo Geisel, Director of the Max-Planck-Institute of Dynamics and Self-Organization, Göttingen, also at the University of in Göttingen, on occasion of his 65th birthday. More about that please see on page 11.

Therefore our 9th International Summer School/Conference "Let's Face Chaos through Nonlinear Dynamics" is a natural continuation of this tradition, again in the same environment as in 2011, 2008, 2005, 2002, 1999 and 1996, namely at the University of Maribor, as one of the activities carried out by CAMTP, in the period 22 June through 6 July 2014. This environment proved indeed to be ideal for such purposes for many reasons, including the rich cultural life offered by the marvelous performances on the world top level of the Maribor Festival Lent, the sportific facilities, the mountains and hiking there, the excellent local Slovenian wines and wine tasting tour, the touristic attractions, our excellent private concerts performed by our young Slovenian musicians, exhibitions of fine arts, excursions through Slovenia, fireworks that accompany the closing of the Festival Lent, etc. This time we shall again enjoy some very interesting public evening lectures.

The scientific programme is covering the broad interdisciplinary and multidisciplinary field of nonlinear dynamics and synergetics, concerning applications and manifestations of chaos in diverse fields of human knowledge, ranging from mathematics to physics and chemistry, from medicine to economy, from biology to engineering, and includes even sociological aspects. It seems natural for us to speak about chaos versus order in an interdisciplinary context. The organizers of this School/Conference share the belief that interdisciplinary trends and developments in science are of primary importance, especially in order to counteract the strongly increasing specialization taking place in the science and technology in our most modern era, however certainly not at the expense of the quality of the disciplinary research: In order to achieve strong interdisciplinarity we certainly need in the first place strong disciplinarity. There is an obvious and urgent need for meetings of this kind, giving an opportunity of scientific exchange among seemingly distant disciplines, and, most of all, allowing students and junior scientists to better understand the role of interdisciplinary research, and to bring them in touch with science in making. And to offer them the opportunity to present their own research work (in short reports and posters). To promote most talented young people from all over the world.

*It should be emphasized that the physics of complex systems, nonlinear dynamics and synergetics are surely one of the major branches of science and research in the 21st Century, along with elementary particles, astrophysics, biophysics, molecular biology, genetics, medicine, economy, psychology, sociology, new technologies like nanotechnologies, almost all of which are in fact also to some considerable extent the area where the nonlinear dynamics is applicable in an important way. As such the nonlinear dynamics paves the way of future science and technology of complex systems in the 21st Century. This includes the future information communication technologies and the socio/economic sciences.*

The level at the beginning of each lecture course (delivered by invited lecturers as a series of

one-hour (60 minutes) lectures) will be adapted mainly to graduate students (who represent the 80% majority) but also will be useful to the advanced undergraduate students (3rd to 5th year), and finally there are also many junior and senior postdocs, junior scientists/professors and senior scientists/professors), whilst in closing the series of lectures (the last third or so) may be and typically will be at the conference level, containing the most recent results comprehensible for the majority of the audience and subject to the discussion among the attending invited speakers, experts and specialists.

The structure of the School & Conference this year will be quite similar to the previous one, the 8th, in 2011.

In the first week we shall have mainly school programme consisting of the following five lecture courses (one hour = 60 minutes):

1. **Stefano Boccaletti, Firenze, Italy, 7 hours:** *Complex networks: Structure and dynamics*
2. **Tassos Bountis, Patras, Greece, 5 hours:** *Mathematical modeling of complex systems*
3. **Anna Carbone, Torino, Italy, 7 hours:** *Challenges in Complex Systems: in particular in socio/economic sciences*
4. **Predrag Cvitanović, Atlanta, USA, 10 hours:** *Introduction to nonlinear dynamics*
5. **Thomas Guhr, Duisburg-Essen, Germany, 5 hours:** *Introduction to econophysics*

The abstracts of the lecture courses are appended at the end of this information brochure. See page 27.

In the second week we shall have the conference programme, but nevertheless the lectures will still be at the colloquium level, thus including a good introduction for the students, nonspecialists and general physics audience. The detailed programme will be set up in the middle of May 2014.

The session for short reports (contributed talks) presented by the participants will be mainly on Saturday 28 July 2014 in the morning until lunch time. The posters will be on display during the entire period of the School/Conference, that is two weeks.

**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

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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 21:00 that we shall celebrate his 65th birthday by a concert, laudatio, and reception.

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## THE PARTICIPANTS

The participants whom we encourage to apply and to attend are:

Mainly:

- **graduate students (Ph.D. students, research students)**

but also:

- **advanced undergraduate students**
- **junior and senior postdoctoral students**
- **junior scientists/professors**
- **senior scientists/professors**

The great majority of the participants is always the graduate students. If you are interested in the scientific topics of our School/Conference, if you are already studying some issues in this field, or if you are even working in the field, or if you are expert in one aspect of the interdisciplinary field of nonlinear dynamics and synergetics, and theory of complex systems, but wish to learn more about the other aspects and other branches of this vast and important field of research, then you are welcome to apply to attend. Please follow the instructions below and observe the deadlines.

## THE SCIENTIFIC COMMUNICATIONS

If you already work in the field, you might have the opportunity to present your work and your results as a **scientific communication**, namely either as a **poster** or as a **short report**. Each participant can present either up to two posters, or one poster and one short report, or just one poster, or just one short report, or no communication at all. A poster can have typical dimensions of 100 cm x 150 cm. The display/exhibition of the posters will last for the entire period of the School/Conference, that is two weeks, and there will be two halls (Dvorana Antona Trstenjaka and Dvorana Borisa Podrecca) devoted to the poster exhibition in the Main University Building, just next to the main lecture hall (**Velika dvorana**). There (in the Halls Anton Trstenjak and Boris Podrecca) we shall serve tea and coffee in the breaks so that the interactions and discussions around the posters will be extremely intense, effective and long-lasting. Therefore the presentation of posters is strongly encouraged and recommended.

A short report (seminar) can be maximally 20 minutes long. Both types of contributions are subject to the refereeing procedure and the acceptance by the Organizing Committee. The category of communication, the title and the abstract, including some key references, should be stated in the electronic Application form, about roughly half A4 page per communication. If you want to increase the visibility of your scientific communications and their assessment then we advise you to include your C.V. and the list of publications in your submission of the Application form. The Application form is available in plain ascii format at the conference home page <http://www.uni-mb.si/chaos/2014/>. This must be filled in and mailed to the e-mail address [chaos@uni-mb.si](mailto:chaos@uni-mb.si). **The deadline** for this type of application is **Friday 16 May 2014**.

Of course, a limited number of communications will be accepted (about 20 short reports, and about 40-60 posters). The acceptance will be based on the principle "first come, first served". Again, it should be emphasized that the posters will be displayed during the full period of the School/Conference (two weeks), which is a very important advantage in favour of the authors, allowing them a thorough presentation and discussion with the interested persons, especially during the coffee breaks, in the mornings and in the evenings. Therefore there will be no special poster session (time interval).

Subject to the willingness of our sponsors **we shall** make arrangements to **award a few of the most outstanding works. The awards will be worth about up to 500.-EUR each.**

## THE PROCEEDINGS OF THE SCHOOL/CONFERENCE

The accepted (selected) and presented communications of the participants will be published together with the lectures of the invited lecturers and speakers in the Proceedings of the School/Conference. The organizing committee plans again, like in 1999/2000, 2002/2003, 2005/2006 and 2008/2008 and 2011/2012 to publish the Proceedings in a special volume of the American Institute of Physics Conference Proceedings. The deadline for submission of the articles (typescripts) will be 30 September 2014, and the publication date will be before the end of the year 2014. The Proceedings will have about 600 pages in total, and should be printed and distributed worldwide. The interested persons can have a look at the Proceedings of the 4th and 5th School/Conference published in special volumes of the *Progress in Theoretical Physics Supplements (Kyoto)* Vol. 139, 2000, Editors M. Robnik, Y. Aizawa, H. Hasegawa and Y. Kuramoto, and Vol. 150, 2003 Editors M. Robnik, Y. Aizawa, and Y. Kuramoto, to see the typical structure and contents of our Proceedings. The Proceedings of the 6th School/Conference were published in 4 issues of the journal *Nonlinear Phenomena in Complex Systems*, Vol. 9, No. 2-3, 2006, Vol. 10, No. 1-2, 2007. The Proceedings of the 7th School & Conference are *AIP Conference Proceeding*, Vol. 1076: Proceedings of "Let's Face Chaos Through Nonlinear Dynamics" 7th International Summer School and Conference, Eds. M. Robnik and V.G. Romanovski, 2008. The Proceedings of the 8th School & Conference are *AIP Conference Proceeding*, Vol. 1468: Proceedings of "Let's Face Chaos Through Nonlinear Dynamics" 8th International Summer School and Conference, Eds. M. Robnik and V.G. Romanovski, 2012. The publications there have a status of a regular refereed article.

## FINANCIAL SUPPORT FOR PARTICIPANTS

There will be available some very limited financial support for most highly qualified participants (only from the economically weak countries !) by various funding institutions, e.g. by the European Physical Society and by the Ministry of Higher Education, Science and Technology of the Republic of Slovenia, especially for participants from the Eastern European (former socialistic) countries (in transition) and developing countries. Excluded are countries of European Union, other countries of Western Europe (like Switzerland), USA, Canada, Australia, Japan, Hong Kong, Singapore, New Zealand, Israel, etc. To apply please register normally (by sending e-mail) like all other participants including sending the advance payment of 600.-EUR and enclose your C.V. and the list of publications. Two letters of recommendation should be sent directly to the e-mail address **chaos@uni-mb.si**. As for this advance payment: Please make a bank transfer to the account of the Summer School/Conference given below. Make sure that all bank transaction expenses are paid on your side, so that the amount will arrive in total (no bank charges upon the receipt). But in every case please send the proof of the payment, namely a faxed copy of transfer to the fax number **+(386) (2) 2355 360**. **The deadline** for applying for financial support is **Friday 18 April 2014**. The candidates will be notified at latest by **Friday 16 May 2014** about what financial support has been approved. If the support is 100% then they will be reimbursed the advance payment of 600.-EUR upon their arrival and registration in Maribor, normally on Sunday 22 June 2014.

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## THE CULTURAL, TOURISTIC AND SOCIAL EVENTS

During the whole period of the School/Conference there will be **the International Maribor Summer Festival "Lent 2014"**, each evening offering at least four to five cultural events (performances), among which you can freely choose, including theatre, opera & ballet, symphonic and chamber music concerts, jazz performances, folkloristic festival performed by groups from all over the world, etc... The quality level is substantial, some of the best artists in the world come to Maribor, especially in the domain of jazz. For example, in 1996 we even had Ray Charles. And much more. All performances are taking place either at various open air places/squares in the old medieval part of the town, called "Lent", by the river Drava, or inside some historic buildings in the same city quarter, or in the opera, theatre or other concert halls in the city. The entrance is free for our participants (it is fully covered by the participation fee), and the entrance tickets (cards) will be distributed together with other conference materials upon your arrival in Maribor. Reservations, if necessary, can be made (in block) for the interested persons by the assisting staff to the Conference (registration desks). The detailed programme (programme brochure) of the Festival performances will be available and distributed upon your arrival in Maribor. The entrance card is the entrance ticket for almost all performances, only for some exceptional events there is a certain but small surcharge. Also, upon your arrival, together with the conference materials, you will receive the book "Facts about Slovenia", to guide you through our country. We shall also have **five private concerts** and other nice social events, and a number of public evening lectures by some eminent thinkers, scientists, philosophers, and engineers.

On Saturday morning, 28 June 2014, we shall have the presentations of the short reports, until lunch time. Then, on the same Saturday afternoon, 28 June 2014, after lunch, there will be a tour through the city of Maribor followed by a wine tasting of some best Slovenian wines in Maribor. On the same Saturday evening there will be the banquet and the closing festivity of the folkloristic part of the Festival "Lent 2014", accompanied by a big firework performance starting at 23:45 and lasting until 00:15.

On Sunday, 29 June 2014, there will be an excursion to some of the most beautiful parts of Slovenia. The participation will be charged extra (about 100.-EUR per person). That will cover everything, the transportation, the (high-level) lunch (at lake Bled) and dinner (in Ljubljana) and the entrance fees (the worldfamous Postojna Cave, one of the largest in the world). For those participants who have already seen this tour alternative excursions will be organized.

Here is the summary of social events:

Monday 23 June: Concert and Welcome dinner, at 19:00

Saturday 28 June: Concert and Conference dinner at 19:00 with fireworks at 23:45 (Festival Lent)

Monday 30 June: Concert and Welcome dinner at 19:00

Tuesday 1 July: Concert and Birthday party: 65th Birthday of Professor Theo Geisel at 21:00

Wednesday 2 July: Concert and Conference dinner at 19:00

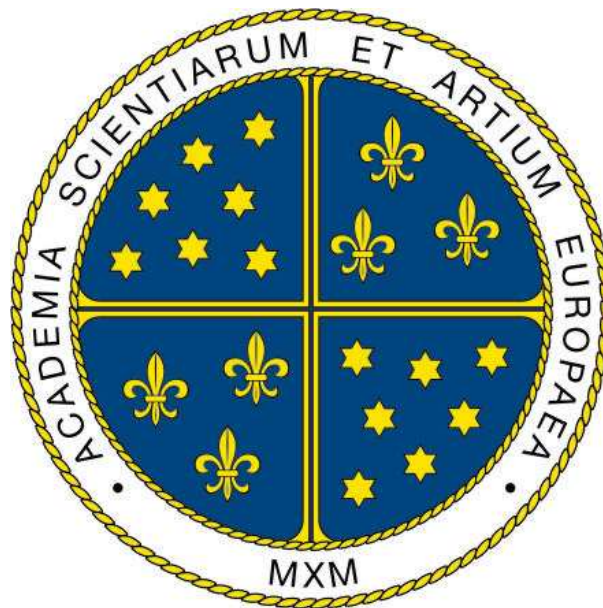
Saturday 5 July: Last dinner at 20:00 with fireworks at 23:45 (Festival Lent)



## THE PATRON OF THE SCHOOL/CONFERENCE

### European Academy of Sciences and Arts (Salzburg)

It is a great privilege that the President of the Academy Professor Dr.Dr.h.c.mult. Felix Unger will visit us on Monday 23 June 2014 at the opening at 09:00 and will deliver his opening address, which will dignify our meeting in Maribor.



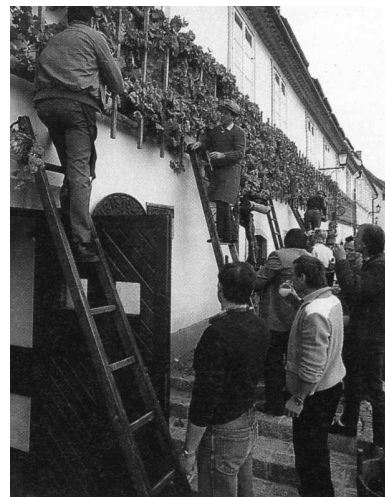
<http://www.euro-acad.eu/>



Main square of Maribor, with plague sign. Mary's Column with the six statues was erected in 1743



Lent, former Maribor landing on the banks of Drava



The oldest vine in Europe

# THE ORGANIZATION OF LIFE DURING THE SCHOOL/CONFERENCE

## The School/Conference will be organized as follows:

Each working day Monday to Friday: lectures 9-10, 10-11; coffee/tea 11-11:30; lectures 11:30-12:30, 12:30-13:30; lunch 13:30-15:15; lectures 15:15-16:15; coffee/tea 16:15-16:45; lectures 16:45-17:45, 17:45-18:45; dinner 18:45-19:45; 19:45 - evening festival programme or other private programmes and activities. Exceptionally we will have a few evening lectures due to the extremely dense programme and high-quality offers by the invited lecturers.

On Saturday morning, 28 June, there will be mainly short reports followed by lunch as on working days. In the afternoon there will be a trip through the Maribor area as described above. On Saturday morning, 5 July, there will be lectures and short reports followed by lunch as on working days. In the afternoon there will be a social event or/and trip to celebrate the closure of the (successful) School/Conference, followed by the Last Dinner.

## The Conference Place:

The lectures will take place in the Boris Podrecca Hall (Dvorana Borisa Podrecce) in the first week, while in the second week in the Large Lecture Hall (**Velika dvorana**) in the Main University Building, on the ground floor (actually semi-basement), at Slomškov trg 15, just next to the Theatre (Slovensko Narodno Gledališče) and Opera. For the details of the location and more about the City of Maribor and its map please see our home page <http://www.camtp.uni-mb.si/chaos/2014/> and the links there. The capacity of the lecture hall is at least 160, and is air-conditioned. The Main University Building is a nicely renovated old 19th Century building, opened in September 2000, in excellent shape with excellent infrastructure. There will be extra internet points for your use during the Conference time, especially to check and to send your e-mails.

The University Library Building is located just behind the Main University Building, in the central and most beautiful square of the city, called Slomškov trg, with the Cathedral situated in central position, and surrounded by the historic buildings of the Theological Faculty, the University Building, the National Theatre and Opera, the central Post Office building. There is a small green park inside, surrounded by many nice coffee houses offering a variety of refreshments, suitable for private discussions in small groups. Also, the Main University Building is just at 8 minutes walking distance from the Hotel PIRAMIDA, at Heroja Šlandra 10, (which normally is the accommodation place for the invited lecturers and those participants wishing explicitly the accommodation there - the latter one at their own extra expenses), and also only at 8 minutes walking distance from the students residence in Dijaški dom DRAVA, at Smetanova ulica 67.

### **The Accommodation:**

**All invited lecturers and speakers** will be accommodated in single rooms (unless requested otherwise) in **Hotel PIRAMIDA, Heroja Šlandra 10, SI-2000 Maribor, Telephone +(386) (2) 2344 400, Telefax +(386) (2) 2344 360**, where they can also register upon the arrival to get the Conference materials. Hotel PIRAMIDA is situated at a central quite convenient location in the City Center, not far from the famous and old Hotel OREL and the nearby baroque City Castle, in the pedestrian zone, and close to the very nice and old City Park. It is 5 minutes walking from Hotel OREL and 8 minutes walking to the Conference place in the Main University Building. It is a 4 star hotel, and it has all the features of best quality, especially the cuisine. In the city we have several superb swimming, sauna, fitness and health centers. One is FONTANA located at Koroška cesta 172, Telephone +(386) (2) 2344 100, which belongs to the same company like hotels Orel and Piramida, namely **Terme Maribor**. Therefore all hotel guests of Hotel PIRAMIDA can use the swimming, fitness and sauna center FONTANA every day free of charge. Just get a voucher at the reception of Hotel PIRAMIDA before going there.

There is a small bus (shuttle minibus) leaving for FONTANA every 30 minutes from Maistrov trg, just next to the City Castle. But you can also borrow a bicycle free of charge.

As mentioned above, PIRAMIDA is just at the 8 minutes walking distance from the Conference place (the Main University Building). All those participants accommodated in Hotel PIRAMIDA will have all meals (breakfast, lunch and dinner) in the restaurants of the hotel. The participants ("students"), normally accommodated in the students residence, will also join us to have lunch and dinner in the restaurants of the hotel PIRAMIDA. This is included in their participation fee.

**The participants** (who are not invited lecturers), will be normally accommodated in single rooms (unless requested otherwise) in the student residence **Dijaški dom DRAVA, Smetanova ulica 67, SI-2000 Maribor, Telephone +(386) (2) 2348 150, 2348 154, Telefax +(386) (2) 2348 170**. The registration office there will be open 24 hours a day. The quality of accommodation meets the standards of a decent hotel. They will have their breakfast served in the restaurant of this residence establishment. For lunch and dinner, they will join the lecturers in the restaurants of the hotel PIRAMIDA, which is included in the participation fee. (Normally it is 1200.-EUR, payable in two payments, the advance payment for 600.-EUR which must be made by transfer in parallel with the submission of the Application form, and the rest for 600.-EUR payable at the registration in cash. The deadline is 16 May 2014. For late applications after 16 May 2014, and before 18 June 2014, the advance payment increases to 850.-EURO, whilst 600.-EURO is the rest to be paid upon arrival in Maribor.) This student residence is very nice, having extra facilities such as fitness rooms, music room with piano, the evening bar (coffee, drinks and refreshments) open until 10-11 pm. The distance from the residence establishment to the Conference place in the Main University Building is just about 8 minutes walking.

**THE HOT LINE (TELEPHONE) 24 HOURS A DAY:****Please call:****+(386) (31) 307 360 (Prof. Marko Robnik)**

If you have any problems (one week) before and during the School/Conference, or even after the School/Conference (one week), there will be open special **hot line (telephone) +(386) (31) 307 360 (Prof. Marko Robnik)** where you can get the requested information, advice and help at any time.

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## THE PARTICIPATION FEE, THE APPLICATION AND THE DEADLINES

The application for the participation is possible only electronically. All information is available on the conference home page:

<http://www.camtp.uni-mb.si/chaos/2014/>

There you will find the Application form as well as the Arrival form, both in plain ascii format. Please fill them in and send them by e-mail to the address [chaos@uni-mb.si](mailto:chaos@uni-mb.si).

If there is any problem please contact us for help at the e-mail address:

[chaos@uni-mb.si](mailto:chaos@uni-mb.si)

**THE PARTICIPATION IS LIMITED TO ABOUT 140 PERSONS**, and is based on the application and invitation procedure. More or less this implies that the admission will be based on the principle "first come, first served", and so the interested persons are strongly advised to apply as soon as possible. When the maximum capacity of 140 accepted participants will be reached, the application procedure will be closed and no further admission will be possible. After receiving their application and the advance payment the candidates - applicants will be notified whether they are admitted - invited or not.

The participation fee normally is 1200.-EUR (before 16 May 2014), whilst for late applications (after 16 May and before 18 June 2014) it is 1450.-EUR.

This participation fee covers the tuition fee and all local expenses, accommodation, all meals with drinks included, banquets, private concerts, Festival Lent entrance fees, the excursion through the City of Maribor, the wine tasting tour, unlimited tea and coffee and other soft drinks during the lecture breaks, except for the trips on Sunday, 29 June 2014.

The important **DEADLINES** are as follows:

**Applications with Abstracts for communications (posters or short reports): 16 May 2014**

(Send the advance payment for 600.-EUR and the copy of the bank transfer by fax to +(386) (2) 2355 360. Cheques are not accepted. The amount 600.-EUR must be paid in cash upon arrival at registration. Your filled Application form with C.V. and list of publications should be sent by e-mail to chaos@uni-mb.si, whilst two letters of recommendation should be sent directly to the same e-mail address chaos@uni-mb.si by the writers of recommendations)

**Normal application \_\_\_\_\_: Friday 16 May 2014**

(Send the advance payment for 600.-EUR and the copy of the bank transfer by fax to +(386) (2) 2355 360. Cheques are not accepted. The amount 600.-EUR must be paid in cash upon arrival at registration.)

**Late application (after Friday 16 May 2014) \_\_\_\_\_: Wednesday 18 June 2014**

(Send the advance payment for 850.-EUR and the copy of the bank transfer by fax to +(386) (2) 2355 360. Cheques are not accepted. The amount 600.-EUR must be paid in cash upon arrival at registration.)

**Application for financial support for participants \_\_\_\_\_: Friday 18 April 2014**

(Follow the normal application procedure including the advance payment and send your filled Application form with C.V. and list of publications to the e-mail address chaos@uni-mb.si, and two letters of recommendation should be sent directly to the e-mail address chaos@uni-mb.si by the writers of the recommendations.)

**Arrival and Reservation Notice \_\_\_\_\_: Wednesday 18 June 2014**

(This form is available in plain ascii format on the conference home page and should be filled in and sent as early as possible to the e-mail address chaos@uni-mb.si)

The advance payment (for normal application 600.-EUR before 16 May 2014, and 850.-EUR for late application after 16 May 2014 and before 18 June 2014) should be performed and the proof of it (faxed copy of the bank transfer) must be received within one week time after the electronic application by e-mail. The bank transfer should go to the account of the Summer School/Conference:

Beneficiary:

**Center za upor. mat. in teor. fiz. CAMTP  
Krekova 2, SI-2000 Maribor, Slovenia**

Beneficiarie's Bank Institution:

**NOVA KREDITNA BANKA MARIBOR d.d.  
Vita Kraigherja 4  
SI-2000 Maribor, Slovenia  
International Bank Account number (IBAN): SI56045150000891647  
SWIFT code: KBMASI2X**

The proof of the payment - a copy of the bank transfer - should be sent obligatory to the fax +(386) (2) 2355 360. Please, on the bank transfer order form, clearly write your full name and surname, the address, the city and the country of your residence. This is required by the new Slovenian law to prevent the international illegal money laundry. If an institution is paying the advance payment for you, then please clearly write the name and the full address of the institution plus your name and surname.

**VERY IMPORTANT:** Please pay all bank transfer charges on your side, as otherwise the receiving bank imposes big charges like up to 50.-EUR per transaction.

**The participants from Slovenia** should pay the advance payment by a bank transfer to the account: (**TRR račun**):

**Center za upor. mat. in teor. fiz.**

**TRR račun: 04515-0000891647**

**pripis: za Poletno Šolo**

and otherwise follow the same procedure as advised above for foreign applicants.

**All the applications must be done electronically-only by sending the Application form by e-mail to the address [chaos@uni-mb.si](mailto:chaos@uni-mb.si). The Application form in plain ascii format, along with all other instructions, is available on our conference home page:**

**<http://www.camtp.uni-mb.si/chaos/2014/>**

**The Contact Address of the School/Conference:**

**CAMTP, Summer School**

**University of Maribor**

**Krekova 2, SI-2000 Maribor, Slovenia**

**Telefax +(386) (2) 2355 360**

**Telephone +(386) (2) 2355 350 and 2355 351**

**e-mail [chaos@uni-mb.si](mailto:chaos@uni-mb.si)**

**Applications without the advance payment will not be processed. Those participants who wish to pay the full participation fee 1200.-EUR for normal application and 1450.-EUR for the late application, already as advanced payment, in total, are welcome to do so. In cases of cancellation for any reason the applicants will be refunded the whole amount except for 200.-EUR cancellation fee. In the unlikely cases of rejected application the full amount will be refunded.**

**All further information** with the current updates is available on our home page address:

**<http://www.camtp.uni-mb.si/chaos/2014/>**

In case of a serious doubt you are welcome to contact the Director Professor Dr. Marko Robnik personally at **[Robnik@uni-mb.si](mailto:Robnik@uni-mb.si)**.



## THE APPLICATION PROCEDURE AND THE ARRIVAL AND RESERVATION FORM

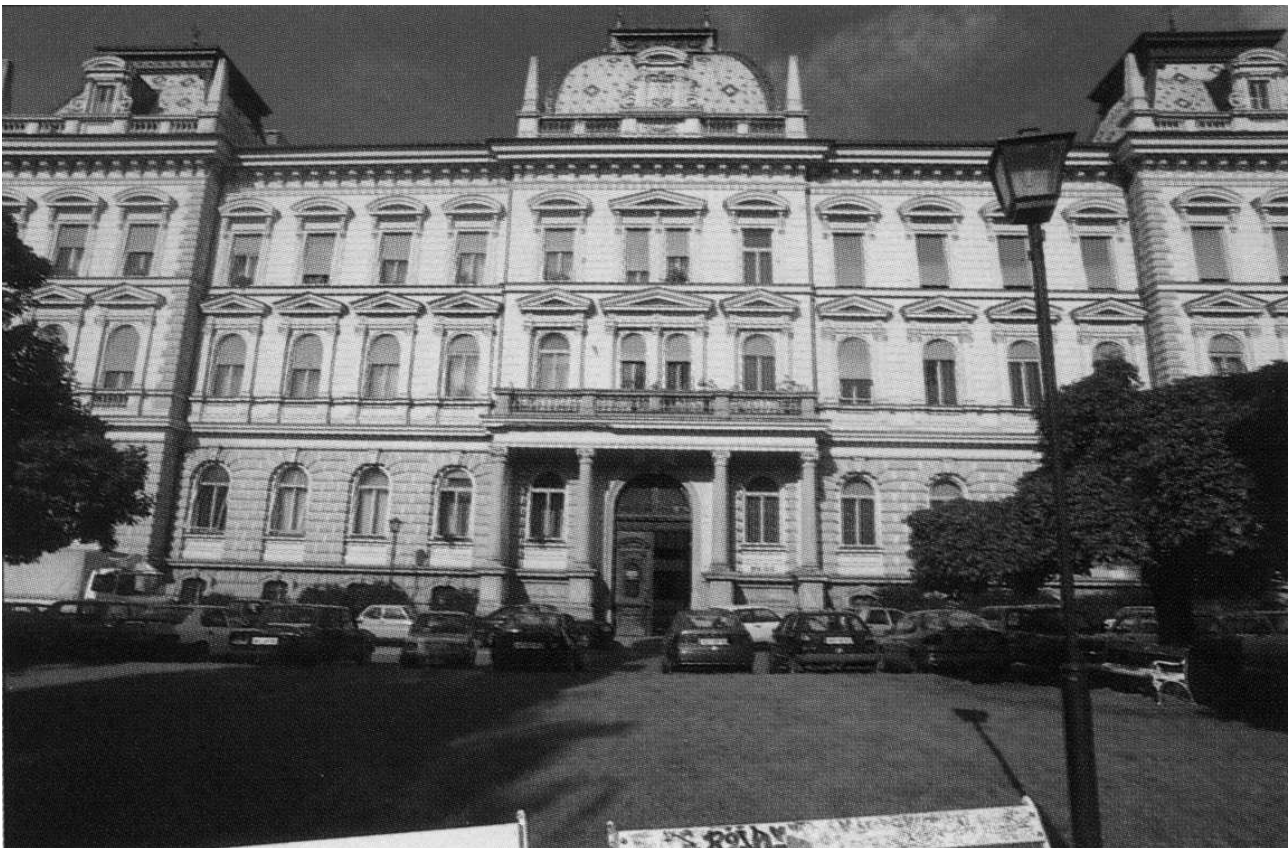
Application is possible **only in the electronic form, by sending an e-mail with the filled Application form to the e-mail address [chaos@uni-mb.si](mailto:chaos@uni-mb.si)**. The Application form in plain ascii format can be found at our conference home page:

<http://www.camtp.uni-mb.si/chaos/2014/>

The proof of the advance payment - a copy to our fax - must be received at our address of CAMTP at latest one week after the electronic application (see above). Then, upon the receipt of the application and of the proof of the advance payment the candidates will be notified whether they are accepted or not, including their **communications**. When sending the payment please clearly indicate your name and the identity (the full address) beyond any doubt. When the maximum capacity of about 140 participants will be reached the School/Conference will be simply closed for all further applications (the status will be available on our conference home page). Thus the organizers strongly recommend to apply as early as possible.

**The Arrival and reservation form** (the form is available at our conference home page given above) should be submitted by e-mail at latest by 18 June 2014, possibly much earlier if you already know your arrival data.

All registered - admitted participants and interested persons registered on the e-mailing list will receive our regular circularies with the up-to-date information on the School/Conference.



University of Maribor, main building

## A WORD ABOUT CAMTP

### **CAMTP - Center for Applied Mathematics and Theoretical Physics University of Maribor, Slovenia**

The Center for Applied Mathematics and Theoretical Physics (**CAMTP**) was founded in June 1990 as a new research institute under the direction of Professor Dr. Marko Robnik and became an independent academic institution (member) of the University of Maribor in July 1991. The financial support is provided entirely by the Slovenian Research Agency, a department of Ministry of Education, Science and Sports of the Republic of Slovenia. Its research activities and collaborations are strongly internationally oriented, and the institute now has already a number of external collaborators and research visitors from among the leading scientists in Slovenia and in foreign countries, especially in Germany, Japan, Italy, Spain, Belarus, Russia, China and USA.

The theoretical research programme covers four dominant fields:

- (1) Nonlinear dynamics of classical and quantum nonintegrable and chaotic systems,
- (2) Mathematical and statistical physics and theory of dynamical systems.,
- (3) Computer algebra,
- (4) Theory of ordinary differential equations and dynamical systems

Some collaboration in the theoretical astrophysics is also involved in joint projects with the researchers of the University of Bonn. **CAMTP** collaborates also with the University of Ljubljana. The Center has bilateral agreements (Memorandum of understanding) with Waseda University, Tokyo, Munich University of Technology, Institute Rudjer Bošković, Zagreb, Osaka Prefecture University, several institutions in Minsk, Belarus, and in Moldova. The Center is one of the supporting and founding institutions of the international interdisciplinary journal *Nonlinear Phenomena in Complex Systems (NPCS)*, founded in 1998, which is published in Minsk, whilst its online version is maintained at **CAMTP**.

The purpose of the Center is to carry out the theoretical research, to maintain the international academic relations and collaborations in these fields, and to educate young research students from Slovenia and abroad. The Center is also the scientific organizer of the Summer Schools/Conferences "*Let's Face Chaos through Nonlinear Dynamics*" held in 1993 and in 1994 at the University of Ljubljana, and in 1996, 1999, 2002, 2005, 2008, 2011, 2014+ at the University of Maribor: The 9th one will be held on 22 June - 6 July 2014, according to the tradition now. Apart from that CAMTP organizes 6 other series of scientific meetings: Christmas Symposia of Physicists, Japan-Slovenia Seminars, European Advanced Studies Conferences, SOCRATES Workshops, Symbolic Computation and Applications and the Out of the Box Conferences.

#### **The address:**

Center for Applied Mathematics and Theoretical Physics  
Director: Professor Dr. Marko Robnik, Member of EASA  
University of Maribor  
Krekova 2  
SI-2000 Maribor  
Slovenia

Telephone: + (386) (2) 2355 350 and 2355 351

Telefax: + (386) (2) 2355 360

e-mail: [Robnik@uni-mb.si](mailto:Robnik@uni-mb.si), **WWW home page:** <http://www.camtp.uni-mb.si>

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# ABSTRACTS OF LECTURE COURSES IN THE FIRST WEEK

## Complex networks: Structure and dynamics

Stefano Boccaletti

*Institute for Complex Systems, Firenze, Italy*

1. Introduction: The network approach to nature
2. The structure of complex networks
  - 2.1. Definitions and notations
    - 2.1.1. Node degree, degree distributions and correlations
    - 2.1.2. Shortest path lengths, diameter and betweenness
    - 2.1.3. Clustering
    - 2.1.4. Motifs
    - 2.1.5. Community structures
  - 2.2. Topology of real networks
    - 2.2.1. The small-world property
    - 2.2.2. Scale-free degree distributions
  - 2.3. Networks models
    - 2.3.1. Random graphs
    - 2.3.2. Generalized random graphs
    - 2.3.3. Small-world networks
    - 2.3.4. Static scale-free networks
    - 2.3.5. Evolving scale-free networks
  - 2.4. Weighted and spatial networks
    - 2.4.1. Measures
3. Synchronization and collective dynamics
  - 3.1. Introduction to synchronization
  - 3.2. The Master stability function approach
  - 3.3. Network propensity for synchronization
    - 3.3.1. Synchronization in weighted networks: coupling matrices with real spectra
    - 3.3.2. Synchronization in weighted networks: coupling matrices with complex spectra
4. Algorithms for finding community structures
  - 4.1. The algorithm by Girvan and Newman
  - 4.2. Other algorithms

# Mathematical modeling of complex systems

Tassos Bountis

*Department of Mathematics, University of Patras, Greece*

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

Anna Carbone

*Politecnico di Torino, Italy*

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-environmental 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 figured 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](http://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](http://www.polito.it/noiselab)

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# Introduction to nonlinear dynamics

Predrag Cvitanović  
School of Physics, Georgia Tech  
Atlanta, GA 30332-0430, USA

## 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](http://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.

### Introduction to Econophysics

Thomas Guhr

*Fakultät für Physik, University of Duisburg–Essen, Germany*

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.

#### References

Mantegna R.N and Stanley H.E. 2000 *An Introduction to Econophysics*, Cambridge University Press, Cambridge

Bouchaud J.P. and Potters M. 2003 *Theory of Financial Risk and Derivative Pricing*, Cambridge University Press, Cambridge

Voit J. 2001 *The Statistical Mechanics of Financial Markets*, Springer, Heidelberg

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### The Production Team:

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**Professor Dr. Marko Robnik**

**Director of the School/Conference**

**Director of CAMTP**

**Final Editing: Benjamin Batistić, CAMTP**

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