CHAOS 2019

Book of Abstracts

12th Chaotic Modeling and Simulation International Conference with Quantum Complexity and Nanotechnology Symposium

Editor

Christos H. Skiadas

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Preface

12th Chaotic Modeling and Simulation International Conference with Quantum Complexity and Nanotechnology Symposium

18 – 22 June 2019, Chania, Crete, Greece

It is our pleasure to welcome the guests, participants and contributors to the 12th International Conference (CHAOS2019) on Chaotic Modeling, Simulation and Applications. We support the study of nonlinear systems and dynamics in an interdisciplinary research field and very interesting applications will be presented. We intend to provide a widely selected forum to exchange ideas, methods, and techniques in the field of Nonlinear Dynamics, Chaos, Fractals and their applications in General Science and in Engineering Sciences.

The principal aim of CHAOS2019 International Conference is to expand the development of the theories of the applied nonlinear field, the methods and the empirical data and computer techniques, and the best theoretical achievements of chaotic theory as well.

Chaotic Modeling and Simulation Conferences continue to grow considerably from year to year thus making a well established platform to present and disseminate new scientific findings and interesting applications.

We are also happy in supporting the Symposium on Quantum Complexity and Nanotechnology celebrating the 60th birthday of Professor Giorgos Tsironis from the University of Crete, a leading scientist in the field. We welcome his friends, colleagues, co-workers and support team presenting high level papers.

We thank all the contributors to the success of this conference and especially the authors of this *Book of Abstracts.* Special thanks to the Plenary, Keynote and Invited Presentations, the Scientific Committee, the ISAST Committee, Yiannis Dimotikalis and Aris Meletiou, the Conference Secretary Eleni Molfesi and all the members of the Secretariat.

May 2019

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Plenary – Keynote – Invited Speakers

Anastasios Bountis

Department of Mathematics, Nazarbayev University, Astana, Kazakhstan

The Effect of Long Range Interactions on the Dynamics and Statistics of 1D Hamiltonian Lattices

Alfred Inselberg

School of Mathematical Sciences
Tel Aviv University
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Visual Analytics for High Dimensional Data

Changpin Li

Department of Mathematics, Shanghai University, China

Dynamics of Hadamard-type fractional differential equation

Wieslaw M. Macek

Faculty of Mathematics and Natural Sciences
Cardinal Stefan Wyszynski University, Warsaw, Poland and
Space Research Centre, Polish Academy of Sciences, Warsaw, Poland

Turbulence in Space Plasmas on Magnetohydrodynamic and Kinetic Scales

Michał Ławniczak,[1] Jiri Lipovsky,[2] and Leszek Sirko[1]

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Peculiar Properties of Open Quantum Graphs and Microwave Networks

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Book of Abstracts

12th Chaotic Modeling and Simulation International Conference with Quantum Complexity and Nanotechnology Symposium

Plenary and Keynote Talks

The Effect of Long Range Interactions on the Dynamics and Statistics of 1D Hamiltonian Lattices

Anastasios Bountis
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I will first review recent results with H. Christodoulidi and C. Tsallis on how the dynamics and statistics of β – FPU 1D Hamiltonian lattices are affected by long range interactions (LRI) in their potential ($1/r^{\alpha}$, $0 \leq \alpha < \infty$) leading to the onset of a weak form of chaos dynamically as well as statistically in the thermodynamic limit [1,2]. Similar effects also occur in 1D Hamiltonians with LRI in the presence of on site potentials of the Klein Gordon (KG) type [3]. I will then report on more recent findings with J. Macias Diaz and H. Christodoulidi, which show that LRI influences significantly the important effect of nonlinear supratransmission in Hamiltonian 1D lattices: Specifically, we find for the FPU case that threshold amplitudes increase the longer the interaction ($\alpha \to 0$) [4] while

for Hamiltonians with KG on – site potentials, there is a sharp decrease of the threshold amplitudes, $0 \leq \alpha < 1.5$ [5], which still remains a mystery!

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Dynamics of Hadamard-type fractional differential equation

Changpin Li
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In this talk, firstly we introduce Hadamard fractional calculus which includes definitions, properties, and definite conditions for Hadamard-type fractional differential equations. Then we present the existence, uniqueness, and continuation of the solution to Hadamard-type fractional differential equation. At last, we define the Lyapunov exponents for Hadamard-type fractional differential equations. And the bounds of these Lyapunov exponents are also determined.

Visual Analytics for High Dimensional Data

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A dataset with M items has 2M subsets anyone of which may be the one satisfying our objective. With a good data display and interactivity our fantastic pattern-recognition defeats this combinatorial explosion by extracting insights from the visual patterns. This is the core reason for data visualization. With parallel coordinates the search for relations in multivariate data is transformed into a 2-D pattern recognition problem.
Together with criteria for good query design, we illustrate this on several real datasets (financial, process control, credit-score, one with hundreds of variables) with stunning results. A geometric classification algorithm yields the classification rule explicitly and visually. The minimal set of variables, features, are found and ordered by their predictive value. A model of a country's economy reveals sensitivities, impact of constraints, trade-offs and economic sectors unknowingly competing for the same resources. An overview of the methodology provides foundational understanding; learning the patterns corresponding to various multivariate relations (linearity, convexity, even non-orientability i.e. Moebius and more) relations. These patterns are robust in the presence of errors and that is good news for the applications. A topology of proximity emerges opening the way for visualization in Big Data.

Turbulence in Space Plasmas on Magnetohydrodynamic and Kinetic Scales

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Turbulence is a complex behavior that still remains a challenge for con temporary science. Space plasmas can be considered natural laboratories for investigating the complex dynamics. In particular, the solar wind is a stream of charged particles (mainly ions and electrons) owing from the Sun with the embedded magnetic _eld; this plasma of solar origin _lls-up the Solar System, including the magnetosheath surrounding the terrestrial magnetosphere. Our previous studies have produced phenomenological models for turbulence in solar wind plasmas on large-(inertial) magnetohydrodynamic scales, based on observations by the Voyager [1] and Ulysses in the heliosphere, and also THEMIS missions in the Earth's magnetosheath [2], where timescales are usually shorter than those in the heliosheath. However, to understand the physical mechanisms governing turbulence in the space plasma environment, it is necessary to investigate the experimental data on even much smaller scale lengths. Therefore, we have considered turbulence using observations from the currently operating Magnetospheric Multiscale (MMS) mission on kinetic (ions and electron) scales, which are far shorter than the scales characteristic for description of plasma by magnetohydrodynamic (MHD) theory, Ref. [3]. We have employed a standard statistical analysis to obtain energy density spectra for the magnetic field strength and the ion speed at high time resolution. It is worth noting that the unprecedented very high-resolution (of about 8 milliseconds) of the magnetic field instrument enabled us to analyze turbulence on scale lengths of only tens of kilometers, i.e. extremely small in the space environment. In particular, it has appeared that a clear break of the magnetic spectral exponent to about -11/2 at frequencies 20 {25 Hz agrees with the predictions of kinetic theory (-16/3). Hence we can hope that the results of these investigations can facilitate a better understanding of the physical mechanisms of turbulence.

Keywords: Turbulence, Space plasmas, Magnetohydrodynamics, Kinetic theory

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Peculiar Properties of Open Quantum Graphs and Microwave Networks

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We will discuss some peculiar properties of open quantum graphs and microwave networks. In particular, we will show that there exist graphs which do not obey the Weyl's law $N(R) = LR/\pi + O(1)$, where $O(1)$ is a function which for R going to infinity is bounded by a constant. The Weyl's law directly links the counting function $N(R)$ of the number of resonances with the square root of energy k, $0<Re(k)<R$, and the total length L of the internal edges of a graph. Graphs which do not obey the Weyl’s law will be called non-Weyl graphs. We demonstrate that for standard coupling conditions the transition from a Weyl graph to a non-Weyl graph occurs if we introduce a balanced vertex. A vertex of a graph is called balanced if the numbers of infinite leads and internal edges meeting at a vertex are the same. We show that the experimental results demonstrating the existence of non-Weyl networks are in excellent agreement with the theoretical predictions.

Acknowledgements: This work was supported in part by the National Science Centre Grant No. 2016/23/B/ST2/03979. J. L. was supported by the internal grant project “Introduction to quantum mechanics on graphs” of the University of Hradec Kralove.

Keywords: Quantum graphs, Microwave networks, Quantum chaos, Open systems, Simulations

Invited Talks, Special Sessions Talks & Contributed Talks

Active Nanoobjects, Neutrino and Higgs Boson in a Fractal Models of the Universe

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Theoretically the relationships of the main parameters of active nanoobjects with the Higgs boson and the Higgs field in a fractal models of the Universe are investigated. Neutrino, nanoparticles, atomic defects, quantum dots can be as active nanoobjects. The neutrino is characterized by the phenomenon of hysteresis. The estimation of the neutrino rest mass is obtained. Using the example of a silica nanoparticle, trapped in an optical trap and placed in a vacuum, estimates of the limiting frequency of rotation of a particle in a laser field with circular polarization and the size of the nanoparticle are obtained. Using the example of atomic defects in boron nitride nanotubes, we obtained estimates of the wavelengths of quantum emission of separate photons. The properties of nanoparticles depend on pressure, state of physical vacuum and cosmological parameters.
Keywords: active nanoobjects, neutrino, Higgs boson, Higgs field, fractal models of the Universe, optical traps, nanoparticles, frequency of rotation, physical vacuum.

Coupled fractal structures with elements of cylindrical type

Olga P. Abramova, Andrii V. Abramov
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By the numerical modelling method the behavior of the deformation field of the coupled fractal structure with elements of cylindrical type was investigated. It is shown that the presence of variable parameters (semiaxes, modules) lead to the stochastic behavior of the complex deformation field. Zero complex displacement field operators are introduced for both separate and coupled elements of the structure. It is shown that the transposition of separate operators in the zero operator for a coupled structure leads to the appearance of a nonzero complex deformation field. At the same time, noise tracks appear on the

background of stochastic peaks. The noise track is a stochastic ring, inside of which is a regular area.

Keywords: coupled fractal structures, complex deformation field, zero complex operators, ordering of operators, numerical modelling.

A Two-photon nonlinear wave in waveguide with graphene monolayer

Guram T. Adamashvili
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A theory of two-photon breathers under the condition of nonlinear coherent interaction of waveguide TM-modes with a two-dimensional layer and a graphene monolayer (or graphene-like two-dimensional material) is developed. Resonance nonlinear two-photon pulses can propagate in the system when the waveguide TM-modes are in resonance with the optically active impurity atoms or semiconductor quantum dots of the transition layer. The optically resonant breathers of waveguide TM-modes can be excited within the McCall-Hahn mechanism, where a nonlinear coherent interaction waveguide TM-modes takes place via Rabi-oscillations of the carrier density, if the conditions for self-induced transparency are fulfilled. When the area of the pulse of waveguide TM-modes is rather small, a breather (0π pulse) is formed. Explicit analytical and numerical expressions for a surface breather (0π pulse) of self-induced transparency are obtained. It is shown that the optical conductivity of graphene exponentially reduces the amplitude of the breather in the process of propagation.

Keywords: nonlinear dynamics, breather, surface waves

Revolving Soliton Clusters in Regular Polygonal Formation

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We report on an intriguing physical phenomenon involving clusters of depression (or dark) solitons orbiting symmetrically and in synchrony along the inner radius of a viscous oil ring. These emerge in a shallow

layer of oil created by a circular flat disk rotating inside a stationary cylindrical container. Groups of 1, 2, 3, 6 and 13 solitary waves were found to travel in unison at a higher velocity than the background waves without changing their shapes. The mutual interaction of the clusters and the background polygonal waves was examined using the experimentally obtained dispersion relationships.

Keywords: solitary waves, dark solitons, vortex instability instability

Roads to chaos in natural convection in an inclined cavity containing nanofluid

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[1,2]University of Algiers, Usthb, Algeria
[3]University Via Domitia, Perpignan, French

We studied numerically the transient laminar natural convection in an inclined cavity containing nanofluid. The fluid is water and the nanofluid is copper oxide (CuO).The horizontal walls are adiabatic and the vertical walls are composed of the two regions of the same size maintained at different temperatures. Transfer equations are resolved using the (stream function-vorticity formulation). We analyzed the effect of Rayleigh number on heat transfer and on the roads to chaos borrowed by the system.The first Hopf bifurcation was observed and the systems are determinist. As the Rayleigh increased multiplicitysolutions are represented by attractors in spaces of phases.We compared results obtained between for two inclinations.

Keywords: Natural convection, Bifurcation, Attractor, Nanofluid

Dynamics of Duffing System with Fractional Order elasticity

Khaled Aledealat
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In this work the dynamics of Duffing system with fractional order nonlinearity is explored. Basically we introduced a fractional derivative to the elasticity term and varied the order of the derivative between zero and two and which allows us to investigate the evolution of the dynamics of the system. Essentially, we will study how the system grow from linear

behavior to nonlinear behavior using phase diagrams, Poincare maps, power spectrum, Lyapunov exponents, and bifurcation diagrams.
Keywords: Duffing system, Chaos, fractional calculus, nonlinear system
POSTER SESSION

Market share dynamics in Vidale-Wolfe and Lanchester models under delayed affine feedback advertising policy

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This paper proposes extensions of the Vidale-Wolfe and Lanchester models of market share dynamics under an affine advertising control policy, which can be subject to two types of delays: in information or in adoption. Information delay refers to the existence of lags in the information used for the advertising policy, while adoption delay refers to the existence of a lag in the effect of the advertising policy. Delays are included to model the natural lags in the flow of information, not considered in several models proposed in the literature. Conditions for stability of the equilibrium market share are derived. In addition, it is shown that oscillatory behavior, Hopf bifurcations and chaos may exist for certain parameter values, and corresponding conditions for these are given.
Keywords: Duopolies, Advertising, Delays, Bifurcations, Chaos, affine feedback control

Multidimensional Effects of combined Chaotic audio and video signals

Asgar Azari
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The multi-dimentional effects of combined chaotic audio/video signals are analysed in particular in terms of the biological effects.The analysis is carried out by showing that cosiderable biological disorders can be treated using combined audio/video signals in particular having chaotic nature. chaotic. non

Infinite Depth Penetration of Electromagnetic Energy Using Chaos Generators

Asgar Azari
Tbriz Islamic Azad University ee dept, Iran

Chaotic generators can be applied to direct electromagnetic energies to an unbounded regions.To do that we need to consider chaotic generators in the elastically bounded regions.

The Attractor of an Iterated Function System

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Iterated function systems (IFSs) have been at the heart of fractal geometry almost from its origins. This talk will discuss our recent research on subjects at the core of the theory of iterated function systems. Particular topics include the role of contractive functions on the existence of an attractor of an IFS, chaos game orbits for approximating an attractor, a phase transition to an attractor depending on the joint spectral radius, fractal transformations between pairs of attractors, and tilings by copies of an attractor.

Keywords: Iterated function system, Attractor, Fractal Geometry.

A Thermocurrent Generator Based on the Photosynthesis System: The Quantum Chaos Approach

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Photosynthesis is the reason of life on the Earth. A phenomenon that inevitable for the living survival. This process has a maximum efficiency that makes nature to reach to this percent of perfectionism. An inspiration of this natural phenomena and applying in the industry has been concerned to the researchers. Furthermore, extensive researches have been done about achieving the electrical current by applying the temperature gradient. In the sense that exerting the temperature gradient

in both sides of the system, is just like applying the potential gradient in both ends of the system and getting the current. We are studying these phenomena in the photosynthesis system with quantum chaos approach. For studying the dynamical behavior of these systems, due to the nonlinear nature of them, the quantum chaos approach can be feasible. Our intended system is the chromosome complex system that found in the green sulfur bacteria's antenna. With absorbing the photons from the sun and! forming the exciton, and transferring to the reaction center, this antenna is the start point of the photosynthesis process. These systems have a cylindrical form that built up from putting the rings up together. Each of the rings contains 18 chromophore. The environment presence is inevitable and it is presumed as phonon sites attached to the chromophores to gain a realistic picture of these systems. To create the temperature gradient, we use quantum Nose thermostat. We can exert our intended temperature gradient by attaching the thermostat to the first and last ring. By using the counter operator as a charge density operator, we can evaluate the passing current from the system and get the current versus to the temperature gradient diagram. According to the diagram, we can obtain some temperature gradient with the maximum current. In addition, with the Multifractal and level spacing distribution diagram in special temperature gradients, we can study the dynamical behavior! and stability of the system in critical points.
This system has a high sensitivity to the temperature variation, so for different temperature gradient, the dynamical behavior of the system is different. For [0-70] K temperature gradients, the multifractal diagram is completely uniform but for some special ΔT, some certain differences are noticeable. The corresponding P(s) for these particular ΔT is close to the Wigner form and reveals the unstable state of the system.
Keywords: Thermocurrent, Photosynthesis system, Chlorosome, Quantum Nose thermostat, Current, Multyfractal and Level spacing distribution

Chaotic flow reversal in the spherical Rayleigh-Bénard convection

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This study investigates the thermal convection in spherical shell under a central force field motivated by an experiment carried in the International Space Station (GeFlow project [1]). The dynamics near the onset of convection is studied by the center manifold reduction and then the dynamics is governed by the amplitude equations. We showed in [2] the existence of intermittent like behavior: long periods of quasi steady-states (axisymmetric or octahedral pattern) followed by sudden excursions to regimes “far” from equilibrium and relamination to another

steady state. In the present case, we focus to flow reversals induced by these intermittencies. In particular, we focus on the chaotic behavior of the reversals and its link with the structure of heteroclinic cycles of steady-states. We show that the spherical symmetry plays a key role in the chaotic dynamics.

Keywords: Spherical Rayleigh-Bénard convection, Flow reversal, Chaotic intermittency, Symmetry-breaking, Simulation

References:

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Adaptation of Coupling Estimation Technique Based on Phase Dynamics Modeling to EEG Analysis During Epileptic Seizure

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In this paper, we consider estimation of couplings between two oscillators from recordings of their experimentally observed variables in application to analysis of interaction between different brain structures during epileptic seizures in coma patients. To analyze those couplings, we use a technique based on constructing a mathematical model of the phase dynamics of the studied systems from discrete sequences of values (time series) of electric potentials, i.e. from electroencephalogram (EEG) recordings. This technique has already shown its effectiveness on etalon systems with different dynamics (including low-dimensional chaos), even in the presence of strong noise, as well as in analysis of real-world systems whose power spectra exhibit a clear dominant peak. However, these conditions are not met for typical EEG signals. The aim of this work is to study the conditions of applicability of this method on the etalon systems whose power spectra reproduce properties of typical! EEG spectra during epileptic seizures in coma patients. In numerical experiments, an ensemble of three noise-driven van der Pol oscillators are used here as a test system, in which two coupled oscillators are driven by the third one. By changing the noise level in the system equations, we control the width of the spectral peaks. Using the technique under study, we have estimated couplings between the oscillators from time series of their phases. Numerical experiments are carried out at different values of the oscillators' parameters. Considerable probability of false detections of couplings in the system is demonstrated. We suggest a diagnostic criterion for possible erroneous conclusions based on the estimation of

the autocorrelation function of the phase dynamics model residuals. We have also tested pre-filtering of signals as a means to obtain more reliable estimates of couplings in case of diagnosed possible problems.

This research is supported by the Russian Foundation for Basic Research (grant No. 18-29-02035)

Keywords: phase dynamics, identification of couplings, ensemble of oscillators

Properties of Discrete Rotation-Translation-Reflection Operations on Closed Loops Generating Basic Patterns like Sinusoidal Waves

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Applying the nonlinear Skiadas concept of discrete successive rotation-translation-reflection operations it is possible to generate a wide range of regular and chaotic patterns on closed loops. Interesting is the emergence of some special basic “linear” patterns like waves, circles, saw-tooth or point-like discrete geometries. It is shown that there are three major properties relevant to the existence of basic closed-loop patterns in lower dimensions:

1.) Every discrete rotation is proportional to a positive power of the inverse radial distance (singularity).

2.) There is a characteristic non-commutation relation, which follows from the temporal order discrete rotation-translation-reflection operators are applied.

3.) A small shift in the translation or rotation parameter can switch between non-local point-like patterns to smooth wave-like patterns.

We will discuss some patterns and the relevance of these simulations to physical quantum systems, where property 1.) is given by momentum conservation and 2.) is a kind of action and momentum quantum for patterns with nonzero mass.

Keywords: Chaotic modeling, Rotation, Translation, Reflection, Closed Loop, Quantum, Chaotic attractors, Patterns, Simulation

Effect of long-range spreading on two-species reaction-diffusion system

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Two-species reaction diffusion system A+B→0 and A+A→(0,A) is studied in presence of long-range spreading. Long-range hops are described by Lévy flights, i.e. by a probability distribution that decays in d dimensions with a distance r according to a power-law function $r^{-d-\sigma}$. Critical dimension dc≤σ depends on the control parameter for the Lévy flights σ<2, and ε expansion is now performed in the form ε=2-σ.
The renormalization group is applied in order to determine the time dependence of the density of reacting particles.
Keywords: Reaction-diffusion systems, Long-range spreading, Perturbative renormalization group, Lévy flights

Surface Roughening in the presence of Long-Range interactions

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Understanding the growth of an interface separating two phases has been been a subject of interest for several decades. Since Kardar, Parsi and Zhang proposed their famous KPZ equation, enormous theoretical advancements have been made by, for example, using renormalization group (RG) methods, mode-coupling approaches, or self-consistent expansions. In this work we focus on the conserved modification of the KPZ equation that describes a different universality class to its non-conservative counterpart. Our main aim is to study the effect of long range interactions. Using methods of field-theoretic RG we investigate its large scale properties. Critical exponents are calculated as a double series of ε and α, where the former describes the deviation from the upper critical dimension and the latter the degree of long-range interactions.
Keywords: Surface roughening, Long-range interactions, Double expansion, Perturbative renormalization group

Realizations of the Snowflake Metric Spaces in the Euclidean Spaces

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Let (X,d) be a metric space and (X,d^{α}) be the so-called snowflaked version of (X,d) whereby $0<\alpha<1$ and $d^{\alpha}(x,y)=d(x,y)^{\alpha}$ for all $x,y\in X$. Assouad's Theorem states that if (X,d) is a doubling metric space than the snowflake metric space (X,d^{α}) can be embedded bi-Lipschitzly into an Euclidean space. Assouad expressed and proved this theorem in 1983 and determined the optimal dimension of the ambient Euclidean space. After then, mathematicians gave different proofs of this famous theorem for the special cases. In this study, we give another alternative proof, which uses the notion of iterated function system (IFS), for $\frac{1}{3}<\alpha<1$ in the case $X=[0,1]$ equipped with the standard metric. We show that for $\frac{1}{2}<\alpha<1$ and $\frac{1}{3}<\alpha\leq\frac{1}{2}$, (X,d^{α}) can be embedded bi-Lipschitzly into $\mathbb{R}^2$ and $\mathbb{R}^3$ respectively as an attractor of a corresponding IFS.
Keywords: Snowflake metric space, Assouad's Theorem, iterated function system

The research of phase transformations order-disorder in Ni2AlNb alloy

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Using the Monte Carlo method [1-3], it is shown that the processes developed during thermal cycling in the course of structural phase transformations in BCC alloys are irreversible. As a result of a heating–cooling cycle, a certain hysteresis is observed, whose presence suggests an irreversibility of these processes, which is indicative of the difference in the structural-phase states in the stages of heating and cooling. In the course of order–disorder and disorder–order phase transformations has supported the difference in its structural-phase states in the stages of heating and cooling. Upon completion of the disorder–order phase transition, domains with L21 superstructure are formed.
Keywords: Monte-Carlo, phase transformations, order, disorder, superstructure, L21, BCC-alloys, crystal

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Logarithmic Solar system

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The quest for the order in our solar system, in which the planets and dwarf planets are distributed; has a long history, but none attempt is close to satisfy this.For this purpose, a mathematical formula based on logarithm was developed. This formula yields the exact semi-major axes for all known planets and dwarf planets along with those proposed ones furthermore applicable to newly discovered solar system. The presence of logarithmic overlapping discs and orderly rather than chaotic distribution of planets and dwarf planets in our solar system, is evident from this approach.

A Class of Möbius Iterated Function Systems

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Iterated function systems (IFS) are primary tools to generate a large class of fractals. A particularly interesting class of IFS are Möbius iterated function systems (MIFS). We characterize Möbius transformations mapping the unit disc of the complex plane contractively into itself. We then give a procedure to produce Möbius iterated function systems on the unit disc.
Keywords: Iterated function system, Möbius iterated function system, Möbius transformation, attractors

Isokinetic curves of the Navier- Stokes equation

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An isokinetic curve is a curve where the velocity is constant. In this paper, we exhibit conditions to have isokinetic curves solutions of the Navier-Stokes equation, especially when the domain is bounded and the external forces don’t depend on time. Locally, the problem can be decomposed in two equations: A Poisson’s equation for the pressure with usual Dirichlet’s conditions and an ordinary differential equation for the velocity depending strongly on the known initial distribution at the origin. When polynomial approximations are justified, the solution is given by power series of Weierstrass-Mandelbrot functions. This method gives many information about the behaviour of the solution and the circumstances of turbulences.
Keywords: Navier-Stokes equation, isokinetic curves, -time, bounded polynomial iterations, Weierstrass-Mandelbrot functions
session 1: Chaos and non linear dynamics
session 5 hydrodynamics and turbulence

Characterization of Interconnected Dynamical Systems Coupling by Complex Networks

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A recently developed method for the evaluation of coupling strength between dynamical systems, based on the entropy quantification of the topology of a cross-visibility network, has been applied for the study of the impact of the El Niño Southern Oscillation (ENSO) on other atmospheric systems and on several climate diseases. The link between ENSO and the Indian Ocean Dipole (IOD) is analyzed, confirming the recently hypothesized influence of IOD on ENSO. This influence is extremely important as it may lead to the amplifications of El Nino oscillation. The problem of the ENSO health links is investigated by mean of its impact on

influenza pandemic events and also by studying the seasonally lagged effects on malaria incidence. The results show the potential of the approach to handle the investigation of real-life complex systems.

Keywords: System coupling, Cross-visibility graphs, Image entropy, ENSO impacts

Consciousness, as an emergent process

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Starting from the wave-corpuscle duality in quantum physics, we propose a model for structuring reality, based on the emergence of systems that contribute to the integration and coherence of the entire reality. Thus, the mind-brain duality, which has been dominating the representation on psyche for a few centuries, could be solved by an informational approach, describing the connection between object and subject, reality and human consciousness, between mind and brain, thus unifying the perspective on natural sciences and humanities. Physical-mathematical models based mainly on (mereo) topology can provide a mathematical formalization path, and the paradigm of information could allow the development of a pattern of emergence, that is common to all systems, including the psychic system, the difference being given only by the degree of information complexity.

Keywords: Emergence, Consciousness, Information, Logics, Brain

Applying the Kernel PCA Method to Reveal the Coexistence of High-dimensional Chaotic and Non-Chaotic Orbits: A Study using a Generalized Lorenz Model

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Based on recent studies using a generalized Lorenz model (GLM, Shen 2019) with various modes, a revised view of the nature of weather has been proposed (Shen et al. 2018), as follows: the entirety of weather is a superset consisting of both chaotic and non-chaotic processes. The coexistence of chaotic and non-chaotic processes suggests that better predictability for nonchaotic processes can be expected if we can identify such processes in advance. In this study, by performing a kernel principle component analysis of various orbits obtained from the GLM, we illustrate that an analysis of the time evolution and spatial distribution of rescaled kernel eigenvectors is effective for the classification of chaotic and non-chaotic orbits and the detection of decision boundaries that enclose chaotic or non-chaotic orbits. To determine tight decision boundaries, we also computed reconstruction errors. The feasibility of applying the recurrence plots for detecting the chaotic and non-chaotic processes is additionally discussed.

The Impact of Solar Weather on the U.S. Telecommunications Industry: A Dynamic Time Series Approach

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Although the impact of solar weather on economic activity appears to be of great importance, very limited work has been done, so far, on the subject. In this work, we examine the dynamic impact of geomagnetic anomalies (Dst index), caused by solar weather, on Earth's economic activity and, more precisely, on the US telecommunications sector, using monthly data that cover the period 1996-2014. We find that the Dst index is Granger causal for the US telecommunication output, which means that the Dst index has predictive ability for the evolution of output in the US Telecommunications sector. Furthermore, by the step-by-step non-

causality approach, we identify the specific lags of the Dst index, for which causality exists. In addition, we test the out-of-sample forecasting ability of the Dst index on the US telecommunications output. Based on our findings, for every out-of-sample forecasting horizon, the comparison of the MAE, MAPE and RMSFE for both best models, AR(p) and ARDL(1,q) respectively, shows that ARDL (1,q) is better in terms of its forecasting ability, which means that the Dst index, which acts as the Distributed Lag (DL) part, provides additional information to the forecasting ability of the U.S. telecommunication output. These results give credit to the impact of solar weather on the US Telecommunications output.
Keywords: Solar Weather, Economic Activity, US, causality, ARDL

A coupled finite element method and multigrid method for fractional diffusion equation: codes in Matlab

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In this new work we develop the coupled finite element method (FEM) and multigrid method (MGM) for fractional diffusion equation. The stability and convergence of these numerical schemes are discussed. Next, a V-cycle multigrid method is proposed to solve the resulting linear systems. Finally, some numerical experiments are given to demonstrate the efficiency of the method.
Keywords: Finite element method, multigrid method, fractional, norm, uniform convergence, V-cycle multigrid method, Matlab

Assessment of the extent of complexity in some original data sets by calculation of Hölder exponent

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Wavelet transform modulus maxima (WTMM) is one of the complexity testing techniques for time series of different origin. In the frame of WTMM analysis, maxima lines of continuous wavelet transform over all scales are investigated as fluctuations. Being recognized as very useful multifractality analysis methods WTMM mainly focuses on quantitative assessment of memorability or long-term persistent features in unknown data sets. It

provides possibility to derive local Hurst exponent at the point x, from the power-law relationship between fluctuation function and time scale. This local H exponent generally is called the Hölder exponent and is estimated from wavelet coefficients. The higher the Hölder exponent, the more regular is considered process given by time series under consideration. In present research, we analyzed complexity or the extent of regularity in different original data sets. Exactly we used seismological, physiological, economical and internet traffic data sets. Considered seismological data sets consisted of, normed to standard deviation increments of earthquake occurrence times, increments of cumulative distances between earthquakes and increments of cumulative seismic energy released during observation period (1975-2017) in the southern Californian earthquake catalogue. Analyzed in this research physiological data sets included arterial systolic and diastolic blood pressure time series of healthy persons and patients with arterial hypertension recorded at Institute of Cardiology, Tbilisi, Georgia. Economic data sets consisted of exchange rate time series of three southern Caucasian countries; Armenia, Georgia and Azerbaijan were obtained from data sets of corresponding central banks. Internet traffic data sets represented pinging recordings collected by our team in Georgia during local election in 2018. According to results of Hölder exponent calculation considered data sets are characterized by quantifiably different extent of complexity. Normed data sets of increments of time, distances and released energies indicate increase in the extent of complexity when threshold of representative magnitude increase from M2.6 to M4.6. Also it was shown that data sets of increments of time and distances are characterized by lower extent of complexity comparing to data sets of increments of released seismic energies. Next, Hölder exponent values calculated for entire length of all available physiological data sets showed that they correspond to persistent non random processes. At the same time, patients with arterial hypertension of the first and second stages are characterized by decreased regularity of the variability of systolic and diastolic arterial pressure. Most noticeably is that in patients with third stage of arterial hypertension extent of regularity in blood pressure variability comes closer to the value observed for healthy group. Analysis of exchange rate data sets indicated that variability of Armenian and Georgian national currency exchange rate is somewhat complex comparing to Azerbaijan national currency, what possible is related with the higher stability of economical development in Azerbaijan comparing to other south Caucasian countries. Hölder exponent calculation of available Internet traffic data sets shows

clear nonrandom character of process and indicates quantifiable changes occurred in the period immediately close to election time. Finally based on our results obtained for different data sets we concluded that Hölder exponent calculation provides interesting insights of analyzed complex processes with no regard of the origin of data sets and obtained conclusions are in general agreement with earlier results obtained in previous researches using other methods of complex time series analysis.
Keywords: Complexity of natural processes, dynamics, scaling, multifractality, Hölder exponent calculation

Light Scattering as a cause of air pollution measurement

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The measurement of aerosol particles, contaminants by light-scattering is greatly complicated by the wide variety of aerosols occurring in the atmosphere. The industrial progress in many great countries of the planet, brought much pollution in the global atmosphere. Smug, particles, oxides, atmospheric temperature, as Entropy. Five variables influence all scattered light measurements: (1) concentration, (2) particle size, (3) particle shape, (4) refractive index and (5) absorption index* (which determines the transparency and color). The most important quantity in air pollution is the concentration, expressed either as mass concentration ("dust load") or the particle number concentration. The quantity second in importance is the particle size which largely determines both the rate of settling and the "visibility" (more precisely, the visual range*) of an aerosol of given mass concentration. Particle shape (1, ! 2) usually has a relatively minor influence on the settling rate. The refractive index usually lies between 1.33 (water) and 2.0 (many minerals), and in this range has less influence on the visibility than does the particle size. The absorption index usually has a minor influence on the visibility except for nearly opaque particles such as carbon (refractive index=2.0, absorption index=0.33). (3) Light-scattering measurements alone cannot distinguish quantitatively between concentration and particle size (even at given values of the other three variables) when a range of particle size occurs.
Keywords: Particles and Wave Optics

Coexistence of Attractors in Coupled Oscillatory System

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Coupled non-linear oscillators are rapidly growing field of research due to complex and rich structure of their dynamics and they have been used to model systems from various branches of science and engineering. Within the paper nonlinearly coupled system is considered with the addition of dissipation term. The system shows chaotic behavior and possesses chaotic attractors for specific values of parameters. Further increase in dissipation removes the chaoticity and transient chaos looks to appear, which is verified by numerical Lyapunov exponents. Some of the prominent bifurcation scenarios are found with the aid of bifurcation detection tool and bifurcation diagrams are plotted, which serve as better understanding of underlying mechanism on route chaos.
Keywords: Chaotic Attractor, Lyapunov exponent, Bifurcation, Coupled oscillators

Chaos distributional systems in MDS with action sub group in homotopy groups of spheres

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In this article we going to study the properties of Chaotic Distributional system in TDS and we going to prove that let a MDS (X,B,μ,T,S) with $T \in C(X;X)$ and the n-tuple $(x_1, x_2,\dots, x_n) \in X^n$ with $n \geq 2$ and X as a compact metric manifold, there exist an independent $J \subset S$ with $S \cong Z$ such that a product set J^n preserve the properties of a positive entropy tuple and contain a periodic set on a ω-limit set if $J \cong E$, being E a smooth variety. Also we going to prove that a MDS with Baire class 2 and an action containing E has always a infinite entropy pair iff there's a proximal set $P(X,X) \subset X^2$ and it's DC2.

Keywords: Scattering system, n-tuple entropy, Proximality, Hopf bundle, DC2

Higher-order perturbation effects in frequency and time-division multiplexed networks under strong dispersion-managed solitons propagating with different energies

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During the last 40 years, optical solitons have been used in broadband optical communication both in time division multiplexed (TDM) and in wavelength division multiplexed (WDM) systems. Through the use of dispersion management (DM) techniques, in which normal and anomalous dispersion fiber segments are alternated, an enhancement of signal-to-noise ratio and also a reduction in several penalties such as Gordon-Haus timing jitter and four-wave mixing (FWM) effects are achieved, thus enhancing the maximum length of optical fiber links. Due to the high bit rates involved in the transmission and to the reduction of the pulse width, an accurate modeling of these systems needs to take into account higher-order effects both in the single-channel and in the multiple-channel case.

In this work we address the effects of higher-order perturbation terms such as third-order dispersion (TOD), Raman scattering and self-steepening in the Generalized Nonlinear Schrödinger Equation describing the evolution of optical soliton pulses in a single and in a multichanneled dispersion-managed transmission link by means of a variational approach. We obtain an ordinary differential equations model for the main parameters of the propagating pulses including TOD, Raman scattering and self-steepening. The variational equations are initially solved for a single pulse in order to identify the launching parameters for a single pulse in the TDM model and for each pulse in each channel in the WDM case and in the first DM cell of the system. The validity of the model is then assessed against the integration of the full nonlinear partial differential equation. We systematically study the residual frequency shift in a WDM network and the interaction distance in a TDM system after the collision between sets of two pulses as a function of the ratio of dissimilar peak powers in a broad range of dispersion difference values, concluding that the transmission characteristics may be improved by means of using specific values of unequal energies and taking into account higher-order correction terms.

Keywords: Optical solitons, Dispersion management, variational approximation, third order dispersion, optical fiber communication

From Tonic Spiking to Bursting in the Nociceptive Neuron Model

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We examine the transition from tonic spiking to bursting for the nociceptive neuron model and demonstrate that the dynamics of the model response to the stimulus exhibits in the existence of various types of bursting in the dependence on the stimulus value. However, the bifurcation mechanisms for the emergence of the both types of bursting are the same. The beginning and the end of the burst discharge are connected with the subcritical Hopf bifurcation and the fold limit cycle bifurcation, respectively. The presence of the fold limit cycle bifurcation in the structure of the bifurcation diagram of the fast subsystem and the torus bifurcation in the structure of the bifurcation diagram of the full system lead to the emergence of special solutions of the type torus canards in the transition from tonic spiking to bursting with changing the stimulus value.
Keywords: Bifurcation analysis, Bursting, Hopf bifurcation, Torus canards, Nociceptive neuron model

Steady-states, stability and bifurcations in multi-asset markets with bounded rational investors

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We develop and investigate a dynamic asset market model in discrete time, in which investors have the choice between two risky assets and one safe asset. Investors' market entry decisions are subject to herding effects and depend on the markets' price trends and fundamental conditions. As it turns out, the dynamics of our model is driven by a four-dimensional nonlinear map which possesses a 'Fundamental Steady State' (FSS), consistent with the standard 'dividend discount' model. Depending on the model's behavioral parameters, the FSS may undergo different types of local bifurcations, namely, a transcritical, flip or Neimark–Sacker bifurcation, all with a clear-cut interpretation in economic terms. While the first bifurcation is associated with a possible over- or undervaluation of the risky assets, the latter two may trigger complex endogenous dynamics

whenever investors' responsiveness to observed price trends or to perceived fundamental mispricing is strong enough.

Keywords: Multi-asset markets, Replicator dynamics, Nonlinear maps, Stability and bifurcation analysis, Behavioral finance

Simulation of Mixed Binomial Distribution to Five-Star Rating Data

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Using the max entropy distribution principle is possible to determine the limiting distribution of five-star ratings, the Truncated Geometric distribution. In normalized entropy chart observed that entropy of real five-star rating data located below the max entropy limit of Truncated Geometric and above the simple Binomial distribution (see fig.1). The area between those two distribution curves can be modeled by a mixture of two Binomial distributions. The first one Binomial of the mixture corresponds to people with negative opinion about the rated entity and the second one corresponds to people with positive opinion.The weighted sum of those two distributions is capable to fill the area between (see fig. 1).

The proposed mixed Binomial distribution is capable to represent almost perfectly the observed distribution of five-star ratings. A sample of 2000 five-star rating datasets from TripAdvisor and Google apps used to confirm the appropriateness of proposed mixture. Also discussed the behavior of fitting, the nonlinearity of Binomial mixture causes sensitive dependence to initial conditions (starting values of parameters).

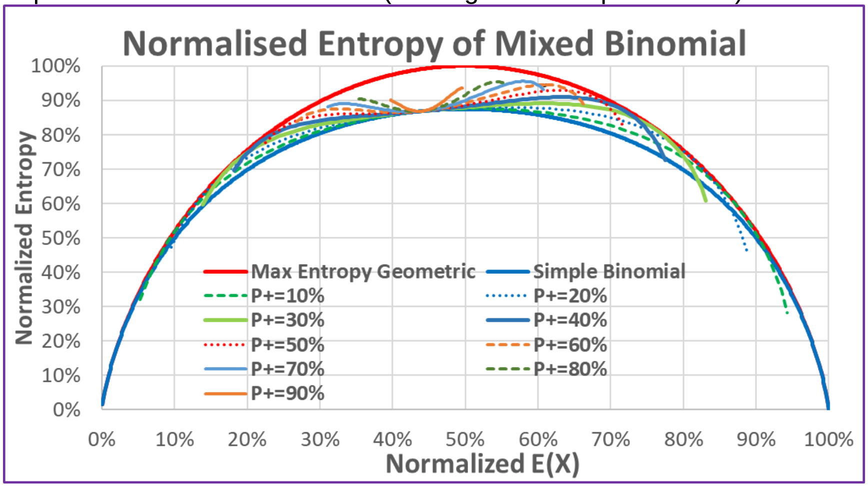

Fig. 1: Entropy Chart of Mixed Binomial

Keywords: Max Entropy Distribution, Truncated Geometric Distribution, Binomial Distribution, TripAdvisor, Five-Star Rating, Google Apps, Entropy Chart.

A three-dimensional ecohydrodynamical model of the Puck Bay "EcoPuckBay". Part 1: Hydrodynamical module

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A new method – 'Integrated information and prediction Web Service WaterPUCK' for investigation influence of agricultural holdings and land-use structures on coastal waters of the southern Baltic Sea is presented. WaterPUCK Service is focused on determination of the current and future environmental status of the surface water and groundwater located in the Puck District (Poland) and its impact on the Bay of Puck (the southern Baltic Sea) environment. It will highly desired tool for land-use and environment management. WaterPUCK combines several different components and methods such as retrospective analyses of existing monitoring data sets, in situ measures and the application of various models to estimate main mechanisms and threats responsible for the pollution transport from the agricultural holdings and land-use structure to the surface and groundwater and potential predictability of environment change of the Puck District and the Bay of Puck ecosystem. The WaterPUCK Service is constructed as part of the project with the same name 'WaterPUCK' (www.waterpuck.pl). Developed within the framework of this project, the model of the Puck Bay "EcoPuckBay" will be a three-dimensional ecohydrodynamical model of high vertical and horizontal resolution that assimilates satellite data. EcoPuckBay model consists of active ocean, ecosystem and ice modules, coupled together with active land module (SWAT plus ModFlow) which provide data, such as freshwater inflow and nutrient discharge from rivers and ground, and passive atmospheric module which provide data such as weather forecasts from external sources (UM ICM). From the side of the open sea, boundary conditions will be fed from the three-dimensional model of the ecosystem for the Baltic Sea 3D CEMBS (www.cembs.pl). The model horizontal resolution is 1/960°, which corresponds to ca. 115 m grid. Vertically model is divided into 19 layers. The first of 5 layers is 0.4 meters thick. 3D EcoPuckBay model will generate 72-hour forecast which include currents, temperature, salinity and ice parameters. In addition, the model will forecast ecological parameters i.e. nutrients, pesticides, dissolved oxygen concentration and biomass of phytoplankton and zooplankton in the entire water column. Each of these variables will be calculated with a second-order advection-diffusion, partial differential equation.

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Keywords: Modeling, ecosystem, Bay of Puck, Baltic Sea

Wave chaos signs in the eccentrically layered spherical cavity resonator with azimuthal homogeneous spectrum

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We developed a rigorous theoretical method for solving the Maxwell's equations in a dielectric loaded spherical cavity resonator with inhomogeneous and asymmetrical filling such as an eccentrically loaded inner dielectric sphere. The method is based on the transition from vector description of electromagnetic fields in the resonator to a description in terms of two scalar functions (Debye potentials) for which we derive the original governing equations. The present theory has no limitation in terms of size of inner sphere, its location inside the cavity or its permittivity value. We have found the solutions of Maxwell's equations for azimuthally homogeneous resonant oscillations and for this case TE and TM modes are separated even for asymmetrical filling of our layered spherical cavity. We obtained the probability of inter-frequency resonant frequencies interval distributions, like Poisson distri! bution in the case of homogeneous resonator without an inner sphere and in the case of a centered inner sphere inclusion. Additionally, we have obtained the probability of inter-frequency resonant frequencies interval distributions like Wigner distribution in the case of eccentric inner sphere. Thus, we have observed geometrically induced wave chaos sign in the resonant frequency of the cavity layered spherical dielectric resonator with the eccentrically loaded inner dielectric sphere even in a dissipation-free cavity.

Keywords: Microwave cavity, spherical layered resonator, frequency spectrum, Poisson distribution, Wigner distribution, probability of inter-frequency intervals distribution

Mosaic patterns in reaction-diffusion systems

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We study a variety of reaction-diffusion processes that lead to the formation of exotic patterns. 1. We carry out precipitation reactions in gel media, wherein the interdiffusion of the co-precipitates takes place from multiple diffusion sources arranged in a symmetric framework. The precipitation zones are delimited by clear polygonal boundaries in congruence with the spatial distribution of the diffusion pools. 2. A displacement reaction in a solid-gel medium is conducted as a carbonic acid diffusion front invades an agar-calcium hydroxide gel putty. The formation of calcium carbonate yields a diversity of patterns, ranging from mosaic structures to Liesegang bands. 3. A Liesegang experiment precipitating lead chromate from the interdiffusion of lead and chromate ions in 2D yields a pattern of rings exhibiting revert spacing. As the diffusion comes from a constantly fed unstirred source (or reactor, CFUR), the patterns transit to a chaotic regime which is sensitive to the initial concentrations used and the flow rate.
Keywords: Liesegang, polygon boundaries, carbonation, lime putty, revert spacing, chaos

Poisson distribution in the distribution probability of chaotic microwave cavity frequency spectrum with symmetrical location of metal rods

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The experimental study of a microwave cavity frequency spectrum with several metal rods including their symmetrical location was carried out. A metal volume cylinder as a microwave cavity was used. We have attempted to validate our experimental results using numerical microwave electromagnetic simulation by means of CST Microwave Studio. The Poisson distribution in the probability of inter-frequency intervals distribution of a chaotic microwave cavity frequency spectrum was detected in the case when the metal rods inside of the microwave cavity

have symmetrical location relative to the center of the microwave cylinder cavity. Other locations of metal rods inside of the microwave cavity make the frequency spectrum as a chaotic one and the distribution probability of inter-frequency intervals becomes similar to Wigner distribution.
Keywords: Microwave cavity, frequency spectrum, Poisson distribution, Wigner distribution, probability of inter-frequency intervals distribution

Global firing rate contrast enhancement in E/I neuronal networks by recurrent synchronized inhibition

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Inhibitory synchronization is commonly seen and may play some important functional roles in E/I neuronal networks. This paper proposes and verifies an idea that inhibitory synchronization could enhance the firing rate contrast globally in E/I neuronal network. First, inspired by the firing rate contrast enhancement phenomenon by the lateral feed-forward inhibition, we reveals that firing rate contrast enhancement could also occur by recurrent inhibition in E/I network. Then we generalizes the idea to inhibitory synchronized E/I neuronal networks. It is found that the synchronized inhibitory neurons act as a global inhibition which can enhance firing rate contrast of excitatory neurons globally in synchronized E/I networks, even in partially synchronized E/I networks. Firing rate contrast enhancement might be an important function of inhibitory synchronization in neural systems.
Keywords: Contrast enhancement; Recurrent inhibition; Inhibitory synchronization; E/I network; Firing rate

A chaotic quantum secure communication scheme base on mixed open system

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Quantum cryptography which is also known as Quantum key distribution is a state of the art approach that represents the features of quantum mechanics in order to guarantee the safe exchange of secret keys. Many Quantum Key Distribution (QKD) systems which are dependent on a

Discrete Variable (DV) are exhibited. We propose a quantum secure communication system dependent upon the correlation of the DV and discuss a Hamiltonian of a particle kicked by a Gaussian beam. This Hamiltonian provides an adequate description of quantum chaotic behavior. In such a system, by applying Einstein-Podolsky-Rosen (EPR) correlation and calculating entanglement parameter we demonstrate that such a system is an appropriate system for cryptography. Based on this model, we introduce a quantum secure communication protocol. By using the Shannon information theory about a detailed analysis of Gaussian cloner attack strategy about this system, we demonstrate that the system is both secure and reliable. The results show that the proposed algorithm improves the problem of the failure of encryption such as small key space and level of security. By calculating the secret information rate ΔI and the Shannon mutual information I(α, ε), the proposed system is proved to be secure against the Gaussian-cloner attack strategy. By focusing on the mutual information I(α, ϵ), we try to know how much information may Eve eavesdrop on the meaningful message in this quantum encryption algorithm. Our results are better than its in previous work. Extracted information by Eve is 0.00333 bits but in similar condition with our work in previous work is 0.1262 bits. Physically, the security of the proposed scheme is guaranteed by the correlations of the DV EPR produced by the NOPA. We can hope that next studies increase encryption speed.

Keywords: Quantum cryptography, Secure communication, Quantum key distribution, Chaos, Discrete variable

Projective Synchronization of Quantum Chaos in Ikeda Map

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A nonlinear ring cavity driven by an external signal is among the most popular models of nonlinear dynamics. For the first time, Ikeda and co-authors studied this model but now special attention to this system is paid in nonlinear optics. One of the popular fields of quantum chaos is addressing quantum maps. Classical maps exhibit the properties of chaotic dynamical systems. Synchronization of chaotic systems means that we want exactly the same as two chaotic systems. Up to now, various types of synchronization and are introduced in dynamical systems, such as complete synchronization, lag synchronization, projective synchronization, generalized synchronization, phase synchronization and so on. At first, projective synchronization was introduced by Mainieri and Rehacek in 1999. In recent years, much attention has been paid on chaos control and synchronization of the discrete-time dynamical system. One

of the strategies that can be considered for synchronization of the system, is the method of slave-master. We introduce Ikeda map to present a new quantum chaotic map. The comparison between analytically studied and numerical simulation results indicate that the proposed method provides good estimates. function projective of quantum chaos in Ikeda map has been studied and a proper controller is suggested to control the systems via Lyapunov theorem. Finally, Numerical simulations have illustrated the effectiveness of the analytical results. It is expected that the new perspective of the Ikeda map can be widely used for audio, video, and still image files encryption, security information transmission, etc. Further, we do hope that our obtained results through this article will pave the way for further studies on quantum chaos.
Keywords: Ikeda Map, Chaos, Synchronization of coupled chaotic map, Bifurcation diagram, Lyapunov exponent

A note on the global posedness of a semi-discrete fractional Klein Gordon System

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We consider a semi-discrete in time Crank-Nicolson scheme to discretize the following weakly damped fractional Klein Gordon Schrödinger system

$$\begin{cases} iu_t + (-\Delta)^{b_1} u + iau = uv, \\ v_{tt} + (-\Delta)^{b_2} v + v + \lambda v_t = -\operatorname{Re} u_x, \\ u(x,0) = u_0, \\ v(x,0) = v_0, v_t(x,0) = v_1 \end{cases}$$

The aim is to provide the necessary conditions of the exponents for which the system is globally well posed in one space dimension.
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Approaches to Estimating the Dynamics of Interacting Populations with Impulse Effects and Uncertainty

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We study the problem of estimating reachable sets of nonlinear dynamical control systems which describe the dynamics of the interactions of predators and their preys under assumption of uncertainty in related initial states. We assume that the uncertainty is of a set-membership kind when we know only the bounding set for unknown items and any additional statistical information on their behavior is not available. Applying results of the theory of trajectory tubes of control systems we present new approaches that allow finding ellipsoidal estimates of related reachable sets. The algorithms of constructing such ellipsoidal estimates are given in two cases, for systems with classical controls and for measure driven (impulsive) control systems. The considered models can describe the behaviour of competing firms, population growth, environmental change, the development of individual industries, etc. Numerical simulation results related to the proposed techniques and illustrating the algorithms are included.
Acknowledgements: The research is supported by the RFBR Project
№ 18-01-00544.
Keywords: Nonlinear control systems, The estimation problem, Set-membership uncertainty, Ellipsoidal calculus, Simulations for uncertain systems

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The Spontaneous Development of Magnetic Fields in the Early Universe from Relativistic MHD Turbulence

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We present the results of Relativistic Magnetohydrodynamic simulations utilizing initial conditions from both the Electroweak and QCD phase transitions in order to study magnetic fields generated via the Biermann Battery Mechanism of Magnetogensis. These simulations occur in a simulated early universe between 10-11s and 10-3s after the Big Bang. We find that magnetic fields greater than 10-19G are generated at small scales and magnetic fields of 10-24G are generated on the Mpc scale. These large-scale magnetic fields represent deviations of 10-100 standard deviations beyond the mean! Further work is needed to understand how these fields may have impacted the large-scale structures we observe today.
Keywords: Magnetohydrodynamic Turbulence, Cosmology, Magnetogenesis

Brain dynamics explained by means of spectral-structural neuronal networks

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Starting from the morphological-functional assumption of the fractal brain, a mathematical model is given by activating brain non-differentiable dynamics through the determinism-nondeterminism inference of the responsible mechanisms. The postulation of a scale covariance principle in Schrodinger type representation of the brain geodesics implies the spectral functionality of the brain dynamics through mechanisms of tunelling, percolation etc., while in the hydrodynamical type representation, it implies their structural functionality through mechanisms of wave schock, solitons type etc. For external constraints proportional with the states density, the fluctuations of the brain stationary dynamics activate both the spectral neuronal networks and the structural ones through a mapping principle of two distinct classes of cnoidal oscillation modes. The spectral-structural compatibility of the neuronal net! works

generates the communication codes of algebraic type, while the same compatibility on the solitonic component induces a strange topology (the direct product of the spectral topology and the structural one) that is responsible of the quadruple law(for instance, the nucleotide base from the human DNA structure). Implications in the elucidation of some neuropsychological mechanisms (memory location and functioning, dementia etc.) are also presented.
Keywords: Fractal brain, Brain dynamics, Neuronal networks, Neuropsychological mechanisms, Brain geodesics

An overview of asynchronous delay iterations: mathematical study and algorithms

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Asynchronous delay iterations from discrete mathematics have long been used to accelerate convergence in high-performance computing. They have the particularity of being defined on an infinite (discrete) set that can be seen as a Cartesian product: at each iteration, a vector of fixed-size bits is updated from a function whose return also depends on a parameter, itself obtained from the first term of a sequence that is iterated at each iteration. The resulting product space is infinite but only handles bounded integers. In addition, only the bit vector must be stored in the finite state machine, a new term of the infinite sequence can be read at each iteration. In doing so, we obtain a discrete dynamic system that can be implemented as is on our computers, but which, from the moment they receive new data at each clock stroke, iterates over an infinite set. Any algorithm performing the function mentioned above, ! and iterating in such a way as to update the machine's memory (the bit vector) from a new input provided to it, is therefore ultimately a discrete dynamic system iterating over an infinite discrete set, and whose chaos can be studied and measured.
Such an approach has proved to be rich in perspectives. Indeed, provided that the above framework is respected, it is possible to design algorithms whose realization on the machine corresponds exactly to the discrete dynamic system studied mathematically: the Cartesian product mentioned above corresponds to all the bit vectors that can be stored in the memory coupled to all the bit sequences that can be provided at the input of the machine, which is indeed an infinite set. This exact framework therefore makes it possible to define and design concretely, and without any shenanigans, programs that have been mathematically proven to be chaotic, and fine-state systems such as Turing's machines that have been proven to be just as precisely chaotic. This framework has been used over the past decade to design algorithms in computer security and hazard

generation, for the Internet of Things, and more recently to design new artificial intelligence algorithms. The purpose of this arti! cle is to review the various theoretical advances in these asynchronous iterations, and in such concepts as the characterization of Devaney's chaos, topological or metric entropy, Lyapunov's exponent and ergodicity, and the concrete algorithmic applications that have been published over the past ten years.

Application of PRNGs to Monte-Carlo Integration Problems

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Random Number Generators (RNGs) based on dynamical systems are very frequently used in many application areas ranging from Monte–Carlo simulations to image –encryption and secure-communication. In many of the studies discrete system s are used in creating pseudo-random generators. For example, logistic map (Andrecut, 1998) and Arnold Cat map (Avaroğlu, 2017) are used as psudo random number geneartors (PRNGs). In this study, we have proposed a pseudo random number generator (PRNG) based continuous chaotic dynamical systems. We test our PSRNGs in the evaluation of integrals with a removable singularity in the range of integration and multidimensional integrations which constitute widely used applications of Monte-Carlo simulations with compare results of our proposed PRNGs with standards on the same problem.
Keywords: Chaotic Systems, Monte-Carlo Integrations, , Random Number Generators

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Chaoticity of transient current behavior and Detrended Fluctuation Analysis parametrization in As2Te3(In) at different temperatures

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Thin films have irregular current behavior under constant voltage. The time evolutions of transient current data for As2Te3(In) thin films were evaluated when the electric field was applied at temperatures of 296 °K, 313 °K, 333 °K and 353 °K. Dc voltages of 0.001 V, 0.002 V, 0.005 V, 0.01 V and 0.1 V were applied at these temperatures. Firstly, the linear auto-correlation function and mutual information technique were used to see delay times with respect to long-range correlations and short-range correlations. These methods give us different time scales and thus a more reliable delay time can be calculated by using the mutual information technique. False-nearest neighbor's method give us convenient embedding dimensions using estimated delay times. We examined the chaoticity by calculating the maximal Lyapunov exponents related to embedding dimensions and delay times with non-linear time series analysis techniques. The current mechanism of glass substrates has variable Lyapunov exponents spectrum at different temperatures. Detrended Fluctuation Analysis (DFA) which evaluates long range power of correlation exponents support the chaoticity of conduction mechanism and the presence of multiple regimes. DFA indicates the varying transition of the crossovers based on different temperatures. DFA characterize the behavior of dc current time series and it is invariant to initial conditions. Below 0.01 V (include that), DFA determined three different conduction regimes through multiple conduction mechanisms. At this region, the crossovers transform between non-stationary state and anti-correlated state. While temperature increases, the current mechanisms set in correlated state. At 0.01 V, the crossovers inclined that current behavior approaches uncorrelated state (white noise) at second regime, but it regains the non-stationary state with varying exponents at different temperatures. On the other hand, at 0.1 V, first crossovers show that the current behaviors initialize from non-stationary state and it approaches Brownian noise. While temperature increases, the current mechanisms have non-stationary state, but they get more correlated values and the current behaviors almost have one regime with correlated state.

Keywords: Chalcogenides, Lyapunov Exponents, Correlation and delay time, Time Series Analysis, Detrended Fluctuation Analysis, Scaling Exponents, Conduction mechanisms

Implementation of a chaotic map for simulation and prediction of temporal turbulent wave front phase fluctuations

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A chaotic map is used for simulation of the phase fluctuations of a point on the turbulent wave front surface which can be considered as a fractional Brownian motion process and local linear approximation method is employed for prediction of its future variations. This can be used in adaptive optics system to predict its fluctuations and provide control signals for develop of phasefront conjugation.

Stochastic turbulent stirring of a non-conserved order parameter

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Functional Renormalization Group (FRG) technique is applied to a stochastical model of non-conserved scalar order parameter near its critical point, subject to turbulent advection. The compressible advecting flow is modelled by a random Gaussian velocity field with the zero mean and correlation function $k^{-d-\zeta}$ Depending on the relations between the parameters d, ζ and the compressibility α, the model reveals several types of scaling regimes. Some of them are well known (model A of equilibrium critical dynamics and linear passive scalar field advected by a random turbulent flow), but there is a new nonequilibrium regime (universality class) associated with new nontrivial fixed points of the renormalization group equations. We have obtained the phase diagram of possible scaling regimes in system. The physical point d=3, ζ=4/3 corresponding to three-dimensional fully developed

Kolmogorov's turbulence where critical fluctuations are irrelevant, is stable for α < 2.26. Otherwise, in the case of "strong compressibility" α > 2.26 the critical fluctuations of the order parameter become relevant for tree-dimensional turbulence. Estimations of critical exponents for each scaling regimes are presented.

Keywords: Stochastic turbulence, Chaotic stirring, Scaling behaviour

Turbulent dynamo in generalized helical magnetohydrodynamic turbulence

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Symmetries and their violation play dominant rôle in the formulation of fundamental models and theories in both classical and quantum physics. We formulate a stochastic magnetohydrodynamics-like model with mirror symmetry breaking. In such a generalized magnetohydrodynamic system the coupling constant, which determines the intensity of interaction between turbulent velocity fluctuations and magnetic field fluctuations, is considered to have an arbitrary value. It turns out that the helicity leads to the appearance of exponential growth of magnetic fluctuations in the region of large space scales. These large scale instabilities caused by the turbulent motion of the electrically conductive medium induce cumulation of magnetic energy, which is transformed into creation of large scale magnetic field. In the language of quantum field theory approach the creation of magnetic field is explained by mechanism of spontaneous spherical symmetry breaking. We ca! lculated the value of generated uniform magnetic field to the first non-trivial leading order approximation in coupling constant.
Furthermore, the perturbations of harmonic Alfven waves in the form of long-lived pulses t exp(- Γ t) (Γ > 0) were found.

Keywords: parity violation, turbulence, dynamo, quantum field theory

Modern field-theoretic and statistical approaches in stochastic systems and developed turbulence, Michal Hnatic

Tricritical directed percolation with long-range spreading

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The effect of turbulent mixing on the model of tricritical directed percolation is studied. The turbulent advecting velocity field is modeled by means of the Kraichnan's rapid change ensemble. The non-equilibrium critical phenomena of one-component reaction-diffusion systems are investigated employing field theoretic renormalization group technique. We give a brief overview of the field-theoretic approach to the problem including renormalization group analysis. The renormalization procedure is performed in the framework of double (**ε**, y)-expansion scheme, where the **ε** is the deviation from, y)-expansion scheme, where the **ε**, y)-expansion scheme, where the **ε** is the deviation from is the deviation from the upper critical dimension dc = 3 and the y is the exponent describing scaling behavior of velocity fluctuations. The corresponding asymptotic behavior is analyzed in leading order of perturbation theory.
Keywords: Tricritical Directed Percolation, Long-range interaction, Field-theoretic renormalization group

Reservoir computing as observers of spatio-temporal chaos

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We demonstrate that reservoir computing can be utilized as an observer for two dimensional dynamics generated by an optoelectronic system. The experimental system consists of a spatial-light modulator with self-feedback that generates complex two dimensional spatio-temporal patterns. The observer successfully cross-predicts the dynamics at all spatial locations based on observed time series from a selected subset of locations. The observer consists of reservoir computing subnetworks that receive input and predict local regions in space only, making the proposed observer resource efficient.

Keywords: Optoelectronic Systems, Spatio-temporal Chaos, State Observer, Chaotic modeling, Recurrent Neural Networks, Reservoir Computing, Simulation, Chaotic simulation

Signal-to-Noise Ratio in Dynamic Stochastic Systems in Stochastic Resonance Mode

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One of the main features of complex self-organizing systems is the set of a priori available states. This gives their evolution an element of surprise, which is reflected as the ability to choose between several results. This is reminiscent of the central problem of the theory of information and communication, namely, how to recognize a particular signal, blurred by noise among the many signals emitted by the source. In some systems, noise can optimize signal transmission, that is, adding a specified amount of input noise can increase the signal-to-noise ratio at the output. The implementation of this phenomenon (stochastic resonance (SR)) in dynamic nonlinear systems is considered in paper. The results of the numerical analysis of stochastic resonance for a dynamic nonlinear system are presented on the example of the Duffing oscillator. Numerical investigated conducted in MatLab.
Keywords: Nonlinear dynamic systems, Noise intensity, Signal-to-Noise Ratio, Stochastic resonance, Duffing oscillator

Chaotic behavior in a thermosyphon model with binary fluid

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Thermoyphons, in the engineering literature, is a device composed of a closed loop containing a fluid who motion is driven by several actions such as gravity and natural convection. Their dynamics are governing for a coupled differential nonlinear systems, and in several previous work we show chaos in the fluid. This work is, in some sense, a generalization of some previous fluids with one-component obtained by A. Rodríguez-Bernal and E.S. Van Vleck [1], when we consider a binary fluid (two-components).
Keywords: Thermosyphon, Asymptotic behavior

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Anisotropic magnetohydrodynamic turbulence near two spatial dimensions

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Influence of the weak small scale anisotropy on the stability of the scaling regimes in the magnetohydrodymanic turbulence near two spatial dimensions is investigated using the field theoretic renormalization group technique in the one-loop approximation of the corresponding perturbation theory.
Keywords: MHD turbulence, small scale anisotropy, scaling regimes, renormalization group technique

Chaos Versus Order: Vivifying Battle Inside A Dissipative Soliton

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We demonstrate that the self-organization in dissipative systems emerges from a random set of initial modes, and this process results in the coherent energy accumulation (dissipative soliton formation) from a noncoherent environment. The vision of a dissipative soliton as an ensemble of quasi-particles trapped inside a collective self-potential is based on the time-spectral duality conception relating the dissipate soliton spectrum with the spectrum of noncoherent light (an indirect consequence of the Van Cittert-Zernike theorem). Such a quasi-particle approach allows applying the methods of kinetic and statistical physics to emergent coherence/decoherence dissipative phenomena, which mimicry surprisingly the turbulence in Hamiltonian systems. The master corse-graining parameter (chirp), which is a measure of the dissipative soliton phase inhomogeneity, defines the transition to turbulence in a time-domain in parallel with the spectral condensation that can result in the

resonant enhancement of sensitivity of mesoscopic structure (i.e., dissipative soliton) to perturbations on the quantum level. We conjecture that the adequate approach to the analysis of these processes combining regular, chaotic, and stochastic phenomena, which range from classical to quantum level, is based on the phase-space representation of nonlinear dynamics. The nonlinear evolution of the Wigner distribution function is chosen as an illustration of this approach. The bi-linearity of this function allows describing the stochastic and quantum processes based on the deterministic nonlinear partial differential equations without increasing the dimensionality. The results are illustrated by examples from the dynamics of partially coherent optical dissipative solitons.

Keywords: Dissipative solitons, Quasi-particle approach to nonlinear dynamics, Van Cittert-Zernike theorem, Wigner distribution function

Micropolar meets Newtonian in 3D. The Rayleigh–Bénard problem for large Prandtl numbers

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We consider the Rayleigh–Bénard problem for the three–dimensional Boussinesq system for the micropolar fluid. We introduce the notion of the multivalued eventual semiflow and prove the existence of the two-space global attractor AK corresponding to weak solutions, for every micropolar parameter K 0 denoting the deviation of the considered system from the classical Rayleigh–Bénard problem for the Newtonian fluid.

We prove that for every K the attractor AK is the smallest compact, attracting, and invariant set. Moreover, the semiflow restricted to this attractor is single-valued and governed by strong solutions. Further, we prove that the global attractors AK converge to A0 upper semicontinuously in Kuratowski sense as K ! 0, and that the
projection of A0 on the restricted phase space corresponding to the classical Rayleigh–Bénard problem is the global attractor for the latter problem, having the invariance property. These results are established under the assumption that the Prandtl number is relatively large with respect to the Rayleigh number.

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Weak signal detection based on chaotic resonance in fractional Duffing system

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Chaotic resonance which has been observed in classical Duffing systems is a phenomenon similar to stochastic resonance but without stochastic noise, in which a system responds to a weak signal through the effects of chaotic activities. In this paper, the chaotic resonance of fractional Duffing system which has stronger depiction ability is studied. Numerical simulations show that chaotic resonance exists in the fractional Duffing system for the given parameters. Based on the principle of chaotic resonance, the system can amplify weak periodic signals. This will provide a valuable reference for weak signal detection in practical problems, and we are currently focusing on this topic.
Keywords: Chaotic resonance; weak signal detection; fractional-order Duffing system

The discrete Lefever-Lejeune equation: Kato-Lai existence-type theorems and insights on the dynamics

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We consider the Lefever-Lejeune nonlinear lattice, a spatially discrete propagation-inhibition model describing the growth of vegetation densities in dry-lands. We analytically identify parametric regimes distinguishing between decay (associated with spatial extinction of vegetation patches) and convergence towards non-trivial attracting sets. To gain insight on the convergence dynamics, a stability analysis of spatially uniform states is performed, revealing the existence of a threshold for the discretization parameter, below which their destabilization occurs and spatially non-uniform equilibrium states may emerge. Direct numerical simulations justified that the analytical stability criteria and parametric thresholds are sharp in distinguishing the relevant dynamics, and revealed the rich structure of the equilibrium set. Connections with the continuous sibling Lefever-Lejeune partial differential equation are also discussed.
Keywords: Lefever-Lejeune equation, lattice dynamical system, existence theorems, pattern formation, dryland vegetation
Acknowledgments: This research is co-financed by Greece and the European Union (European Social Fund – ESF) through the Operational Programme (Human Resources Development, Education and Lifelong Learning 2014–2020) in the context of the project "Localized and quasiperiodic solutions for partial differential equations: Dynamical paths from mathematical ecology to nonlinear physics" (MIS 5004244).

Intermittency of Chaos Functions and the Belousov-Zhabotinsky Reaction

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Intermittent time series generated by the one-dimensional (1-D) solvable chaos map consisting of time-dependent chaos functions are firstly presented, without the accumulation of round-off error caused by numerical iterations. Then, the 1-D map is applied for deriving a 2-D solvable chaos map corresponding to the Belousov-Zhabotinsky (BZ) reaction, which is known to have chemical waves in time. Finally, discrete limit cycles with chaotic dynamics and the pattern formation depending on the system parameter are obtained numerically by considering the bifurcation diagram, and are discussed on the basis of the numerical result for chemical cells of the BZ reaction, as one of non-equilibrium open systems.
Keywords: Intermittency, Chaos function, 2-D solvable chaos map, Belousov-Zhabotinsky reaction, Bifurcation diagram, Limit cycle, Pattern formation, Non-equilibrium open system.

Reaction-Diffusion Systems and Propagation of Limit Cycles with Chaotic Dynamics

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Travelling wave solutions to reaction-diffusion systems are considered from the standpoint based on chaos functions. Firstly, the Fisher-KPP equation, which describes a model for the propagation of gene, is introduced as particle physics, and is transformed into a two-dimensional (2-D) system of nonlinear differential equations. Then, 2-D solvable chaos maps corresponding to the 2-D system are derived, and the bifurcation diagrams are numerically calculated for finding the system parameter to generate limit cycles, which are discrete and have chaotic dynamics. Finally, the limit cycles are discussed by presenting properties of the so-called entrainment and synchronization, and by illustrating the propagation of limit cycles as travelling waves on the original plane.
Keywords: Reaction-diffusion system, Fisher-KPP equation, Chaos function, Bifurcation diagram, Limit cycle, Entrainment, Synchronization, Travelling wave

Modelling of Multiphase Flow as Random Process

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Basic equation array of differential equations was proposed for a multiphase flow considering the probability of each phase in a flow. The main analysis focused on a two-phase flow. The conservation equations for the mass, momentum and energy were obtained under the assumption that all parameters of the interacting phases play the statistical process. In parallel, dynamical system by the Kolmogorov's theorem for two states of a statistical system (phases of two-phase mixture) was considered. Probability of phases was taken further for comparison with the probability and parameters of a two-phase flow from the equations of flow dynamics. Analysis of the parameters was performed for the available flow regimes and on the condition that probability varies from 0 to 1. Correspondence of parameters by the equation array for flow dynamics and by solution of the dynamical system of two interacting statistical states revealed the values of coefficients for dynamical system, expressed in terms of the flow parameters. The results obtained were stated for further discussion and comparison with the experimental data and with results of other researchers of multiphase flows.
Keywords: Two-Phase, Flow, Mixing, Kolmogorov Theorem, Chaotic, Modeling

Chaos synchronization in nonlinear networks with time-delayed and fluctuating couplings

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Nonlinear networks with time delayed couplings have a trend to become chaotic. In general, we distinguish between two kinds of chaos, strong and weak, depending on the scaling of the maximal Lyapunov exponent with the delay time. Only units with weak chaos can synchronize, the trajectory is still chaotic but all units have the same trajectory. We relate chaos synchronization to the eigenvalue gap of the coupling matrix and the greatest common divisor of the loop lengths. As a consequence, rings with unidirectional couplings cannot synchronize. But if additional time delays with specific ratios are added, even rings show chaos synchronization.
Recently, we investigated networks with fluctuating couplings. We consider a uni-directional ring with fluctuating short-cuts. Chaos synchronisation is determined by three time scales: Node dynamics, delay

time and the time scale of the fluctuating connections. For fast fluctuations, chaos synchronisation can be stabilized even when the static network is unstable. Stability is determined by a linear theory. Analytical results relate the stability to an effective static network topology: For fast fluctuations we obtain the arithmetic mean of the coupling matrix whereas for slow fluctuations the effective network is the geometric mean.

Keywords: Chaos synchronization, time-delay, fluctuating couplings

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Chaos in networks with time-delayed couplings
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Chaos in Demand Management Models

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In a scientific work presents a synergistic approach to creating models of demand for products and services, non-linear mathematical model of steady demand management and the results of computer modeling problems. Explore the area of sustainability, attractors of system and the scenario of possible emergence of chaos.
Researches within the project on management of steady demand resulted in the following results:
1. The dynamic nonlinear model of demand – the offer, provided by system of the evolutionary equations, where as the main variables the consumer budget and the income of the consumer is used is developed. It is shown that if demand is rather fully described by the specified set of variables, then it has the unique steady condition - a limiting attractor the cycle representing fluctuation of the income around optimum value. The value itself is determined by the operating parameters. The transition to self-oscillating mode demonstrates that significantly increase their income consumer can not.
2. The controlling variables, which essentially change a situation are probed. In this regard, reviewed the process of managing change in demand due to changes in the consumer budget. Computer modeling

shows change ofconsumer preferences towards products and services of the increased comfort.
The computer control system for steady demand based on synergy model, allows to make fixed monitoring of demand on the basis of phase trajectories of development, to determine steady conditions of demand, to manage demand on the basis of modeling of managing parameters, to perform search of steady optimal solutions, to build the strategy of behavior in the market in the conditions of the competition.
3. Dynamic management model by demand taking into account attraction of a bank loan is constructed. Emergence of new steady limiting cycles, which configuration reflects degree of complexity of the economic activity necessary for stability in the conditions of rigidity of credit liabilities is shown. The chaotic behavior in these conditions is observed.
4. At a computer research such ratio of values of the operating parameters, at which there is an opportunity to appear in a chaotic attractor of Lorentz has been found. This situation is not predicted as the chaotic attractor arose only at a certain combination of the operating parameters. Therefore, having changed values of some of them, , it is possible to avoid area of anattraction of a chaotic attractor. Researches showed that the main parameter conducting system to chaos is the loan capital in the form of the credit.
Keywords: Economy, Demand, Dynamic nonlinear modeling, Model of demand for products and services, Chaotic simulation

Effects of a randomly moving medium on a random kinetic growth: renormalization group analysis near d=2

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The effects of a randomly moving environment on a randomly growing interface are studied by the field theoretic renormalization group analysis. The kinetic growth of an interface (kinetic roughening) is described by the Kardar–Parisi–Zhang stochastic differential equation while the velocity field of the moving medium is modelled by the Navier-Stokes equation with an external random force. The fixed point coordinates, their regions of stability and the critical dimensions related to the critical exponents (e.g. roughness exponent) are calculated in the one-loop approximation.
Keywords: kinetic roughening, renormalization group, passive scalar advection, scaling
Modern field-theoretic and statistical approaches in stochastic systems and developed turbulence.

Electrodynamic analysis of antennas based on chiral metamaterials by the singular integral equations method

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Our research has shown that using of chiral metamaterials in antenna technology makes it possible to improve their electrical and mass-dimensional characteristics. In particular, the using of metamaterials makes it possible to compensate for the reactivity of electrically small antennas. Metamaterial substrate allows improve the directional properties and reduce the mutual influence between emitters. The latter fact is very important for ensuring the electromagnetic compatibility of emitters system compactly located on a small area or on a moving object. On the other hand, great difficulties arise with electrodynamic analysis and the synthesis of similar structures, including chiral metamaterials. Currently, the most common tools for performing electrodynamic analysis of structures with metamaterials are electrodynamic modeling software packages such as Feko, CST Studio, HFSS and other, which require significant computer power. In addition, the algorithms and numerical calculation methods used in these software packages are very common, therefore it is very difficult to find the errors of the obtaining solutions. In this regard, the method of singular integral field representations [1-3] is proposed to be used to calculate the characteristics of antennas located on metamaterials substrates. This method is based on the transition to singular integral equations, the numerical solution of which is a correct mathematical problem. The report presents the results of calculating the characteristics of antennas based on chiral metamaterials by singular equation method. The convergence of obtained solutions is also investigated in the paper. It is shown that singular equations method allows to provide a high accuracy of the calculation of antenna characteristics with relatively small requirements for computing resources.
Keywords: chiral metamaterial, antenna, singular integral equation, convergence

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Improving the MIMO systems efficiency by using antennas based on chiral metamaterials

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An urgent task in mobile radio networks is service quality of improving. This is especially important now, since the requirements for signaling have appeared not only in telephony, but also in multimedia data in real time, such as streaming video. This task is proposed to be solved by using an integrated approach to the modernization of the entire system as a whole. The hardware is required in the improvement along with the modernization of the software part of the data network (the using of various modulation types, signal-code constructions, etc.). MIMO technology is one example of the implementation of this approach, the essence of which is to organize several weakly correlated subchannels of information exchange between the source and receiver. In this paper, the new types of antenna systems using, including those based on metamaterials, is proposed for the further development of MIMO systems. Metamaterial is an artificial composite material with electrophysical properties that natural materials do not possess [1, 2]. In particular, chiral metamaterials are considered in the paper. A chiral metamaterial is a dielectric container in which conductive inclusions of a mirror-asymmetric form are evenly distributed. The use of metamaterials in antenna technology allows us to improve their electrical and mass-dimensional characteristics of radiating systems. For example, the reactive component of the input resistance in a certain frequency range (in which the electrical dimensions of the emitter are relatively small) can be compensated by using metamaterials with negative values of effective permittivity and effective permeability. The using of such metamaterials leads to a decrease in the size of the antenna and simplify the antenna-matching devices. In addition, the using of metamaterials can reduce the mutual influence of emitters in antenna arrays. The latter effect is especially important in terms of using such antennas in MIMO systems. The study of the possibilities of increasing the transmission bandwidth in MIMO systems was studied using antennas with substrates of biisotropic and bianisotropic chiral metamaterials based on left- and right-handed helices. The using of chiral metamaterials substrates based on helices reduces the mutual influence between the emitters and thereby increase the throughput of MIMO systems.

Keywords: Microstrip antenna, chiral metamaterial, MIMO, bandwidth

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Origin of wave gravitational field with point of view of the statistical theory of cosmogonical body formation and the theory of retarded gravitational potentials

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This work investigates wave processes in orbital motion of planets and the stability of exoplanetary systems based on the statistical theory as well as the theory of retarded gravitational potentials. The statistical theory for a cosmogonical body forming (so-called spheroidal body) has been proposed in our previous works. Beginning with the conception for forming a spheroidal body inside a gas-dust protoplanetary nebula, this theory solves the problem of gravitational condensation of a gas-dust protoplanetary cloud with a view to planetary formation in its own gravitational field. The proposed statistical theory of cosmogonical body formation predicts statistical oscillations of orbital motion of planets around stars. Here we explain how the stability of orbital body (a planet) moving around central gravitating body (a star) is reached by the wave gravitational interaction between them. It is well-kn! own that the Alfvén–Arrhenius's radial and axial oscillations modify the forms of planetary orbits. Using the statistical theory of cosmogonical body formation we find that periodic temporal deviation of the gravitational compression function of a spherically symmetric spheroidal body (under the condition of mechanical quasi-equilibrium) induces an additional periodic force. In this connection, we represent the specific additional periodic Alfvén–Arrhenius force by means of the series of spectral components with multiply ordered frequencies to the average main circular frequency. Within framework of the developed theory of retarded gravitational potentials the formula of additional periodic force (as well as the wave gravitational potential relation) is also derived. We show that energetic wave exchanges between the central gravitating body and the orbital moving body seem be effected in the different spectral domains. Therefore, the orbital motion of body should be! considered in a fast oscillating wave gravitational field. Th! is conclusion is entirely confirmed by existing Alfven–Arrhenius' radial and axial oscillations of bodies on orbits.

Keywords: Gas-dust protoplanetary nebula, Gravitational condensation, Exoplanetary systems, Alfven–Arrhenius' oscillating forces, Energetic wave exchange, Stability of planetary orbits

Comparative analysis of critical exponents in diverse dimensions: epsilon expansion and conformal bootstrap approach

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Based on the recent calculations of critical exponents in various dimensions ($2 < d < 4$) obtained by the Conformal Bootstrap method for the Ising universality class, we present the numerical estimates of the exponents obtained by means of the Borel resummation of the six-loop epsilon-expansion. For a wide range of spatial dimensions, the values of the exponents obtained by both methods systematically differ from each

other. The results obtained set the difficult problem of identifying and understanding the origin of such discrepancy between the perturbative and nonperturbative approaches. Possible reasons for this diversity and further directions for investigating the problem are discussed.
Keywords: conformal bootstrap, conformal field theory, renormalization group, critical exponents, epsilon expansion

A Spectral analysis of Chaotic oscillations in the model of the Chua's circuit with smooth nonlinearity developed with use of matrix decomposition

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The A. M. Krot's matrix decomposition method developed for analysis of complex nonlinear dynamical system attractors that based on matrix series in the state space has been used for nonlinear analysis of Chua's circuit with cube non-linearity. It is shown that the operator of the system of Chua's differential equations can be represented through the linear, quadratic and cubic terms of the matrix series. The obtained terms are the basis of the simulation model used for carrying out computational experiments. Using the results of the experiments, the values of the control parameters, which lead to the chaotic regime, are determined, as well as bifurcation and spectral analysis of the generated signals are carried out. It allows to prove the transition to chaos through a series of bifurcations. The research allowed to draw a conclusion that the process of occurrence of chaotic oscillations in the Chua's circuit corresponds to the L. D. Landau's model of initial turbulence in full accordance with the theory of Ruelle-Takens. The correctness of application of the matrix expansion of a vector function depending on values of the perturbations (increments) of variables in the state space is investigated.
Keywords: Nonlinear dynamical system, Chua's circuit, chaotic attractor, matrix decomposition method in the state space, Chua's circuit computational model, spectral analysis of chaotic oscillations, the theory of Ruelle-Takens.

Evolution of Basin Entropy and Existence of Fractal Basin Boundaries in a Galactic Model

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We have numerically investigated a nonlinear galactic model in the framework of Circular Restricted Three-Body Problem. The multivariate Newton-Raphson method is applied to analyze the shape of basins of attraction associated with equilibrium points. The effect of variation of parameters on the shape of basins of attraction and the number of iterations required for the convergence of initial conditions to equilibrium points is illustrated with various graphs and data. We carry out an exhaustive numerical investigation to show the influence of these parameters on converging regions in basins of attraction. The degree of disorder and existence of fractal basin boundaries are examined with the help of basin entropy. Our numerical results indicate that these parameters have considerable impact on the phase space structure of this dynamical system.
Keywords: basin of attraction, basin entropy, elliptic restricted three-body problem, Newton-Raphson method, fractal basin boundaries

Complete Replacement Synchronization of Chaos in Generalised Lotka Volterra Models via Adaptive Control Method

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The dynamics of multiple interacting species is often complex and the forecasting results of causing a small change in something of large communities are complex to describe. This paper announces an eight-term 3-D chaotic generalized Lotka-Volterra (G.L.V.) model with two quadratic and two cubic non-linearities, which is modeled by a set of equations that represents the dynamical behaviors of prey species, middle -predator top predator. The phase portraits of the Generalized Lotka Volterra model is displayed and the mathematical properties are discussed. The proposed 3D-system has three fixed points, which all are unstable. We show that the fixed point at the origin is always a saddle point, while the other two fixed points depend upon the parameter values. The Lyapunov Exponents of the system are received as L1 = 0.001878, L2 = −.0072791 and L3 = −0.01408. So, the Maximal Lyapunov Exponent of the system is obtained as L1 = 0.99995, which is positive, it gives us the idea that the system has chaotic behavior.Also the Lyapunov

dimension of the system is received as D = 1.0255. Since the sum of the Lyapunov exponents of the system is negative, it directs us to dissipating behavior of the system.The main aim of this work is to synchronize two identical chaotic generalized Lotka-Volterra models with two different initial conditions. First,simple linear controller are designed to synchronize two identical chaotic GLV models via CR technique.Next, nonlinear adaptive controllers are designed to accomplish synchronization of the two identical G.L.V. systems with unknown parameters. The main adaptive results for stabilization and synchronization are established using Lyapunov stability theory. Finally,MATLAB test runs are shown to illustrate the effectiveness of all main results received from this work.

Keywords: G.L.V. Chaotic Dynamical System; Lyapunov Exponent; Chaos; Synchronization Manifold; Unidirectional Complete Replacement Coupling; Adaptive Control Method

Chaotic communication systems

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In our time theoretical and practical studies of communication systems, built with the use of deterministic chaos, both on the software and hardware levels, are actively continued. This work is a continuation of the cycle of works performed at the Department of Radio Engineering and Information Security of the Chernivtsi National University and devoted to the analysis of safe chaotic communication systems. The preliminary analysis of chaotic oscillations, which is planned to be used in communication systems, is performed by the research complex represented in the work. It gives the possibility to estimate a number of important parameters - Lyapunov's indices, the Poincaré cross section, correlation dimensions and others, and evaluate the suitability of the use of the investigated chaotic oscillations for the protection of information. Since simulation of information processes of chaotic systems occurs using pseudo-chaotic oscillations, considerable attention is paid to the boundary between chaotic and pseudo-chaotic, random and pseudo-random oscillations.

Keywords: chaos, pseudo-random sequence, pseudo-chaotic sequence, cryptography, confidentiality of information transfer

Decision-making in a context of uncertainty

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The decision process is considered as the key element for the smooth operation of the systems. For non-complex or linear systems, this process usually follows clear rules or requirements, so that the decision will be easy to make without any difficulty. In the case of complex (non-linear) systems, the decision-making process is repeatedly challenged problems because of the interactions of several factors at the same time and because of the hazards characterizing these factors.
This situation will worsen further if the system goes out of its normal operating range to fall into uncertainty.
In this paper, we will try to make our contribution, to arrive at simplifying the decision-making process, while playing on human factors (ability, anticipation, risk-taking, etc.). As this process can be improved by the development of intelligent decision support tools.
Keywords: Decision process, Complex systems, Intelligent decision support tools, Rules & prescriptions, decision making.

Causality Detection using CD-DDA

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Cross-dynamical Delay Differential Analysis (CD-DDA) is a new tool to study causal connections between time series signals. Based on embedding theory, the classical formulation of Delay Differential Analysis (DDA) relates the differential and delay embeddings of a single time series in a functional form to uncover dynamical differences in the data. The features obtained from DDA provide a powerful basis for time-domain classification of data. In CD-DDA, we extend DDA to detect causal interactions between time series.
First, we validate CD-DDA on coupled dynamical systems, such as the Lorenz and Rössler systems and networks of Izhikevich neurons. After validation, we apply CD-DDA to intracranial electroencephalography (EEG) data of patients with intractable epilepsy to study information flow between brain areas before and during epileptic seizures. We can detect onset zones for seizures and see in some patients a change of information flow up to 4 hours before seizures occur.
Keywords: Causality, DDA, EEG, epilepsy

Photoabsorption profile and satellite features of sodium *a(3s-3p)* perturbed by ground Lithium atoms

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The study of pressure-broadened profile of alkali metals in the presence of parent or foreign atoms, has in recent years become a subject of great importance in astrophysics, spectroscopy, quantum chemistry, and laser physics. Exploring the photoabsorption spectra of the alkali-alkali systems and locating the position and origin of the possible satellite peaks allow us to study the physical and chemical properties of the atmospheres of astromonic objects dominated by alkali-metal atoms.
This work deals with the pressure-broadening phenomena which undergoes the sodium Na (3s/3p) perturbed by ground Lithium Li (2s) atoms. The *a(3s/3p)+Li(2s)* potentials, as well as the transition dipole moments, are carefully constructed and their accuracy is established by determining the vibration-rotation levels and the radiatives lifetimes of the excited molecular states. The result shown that the *aLi* photoabsorption spectra is dominate by the singlet transitiosns and exhibits in the red wing a satellite feature around the wavelength 685nm, attributed to the A←X transitions. The spectra revealed also the appearance of two peaks in the blue wing at the positions 574nm and 490nm originating from the triplet b←a and c←a transitions, respectively.

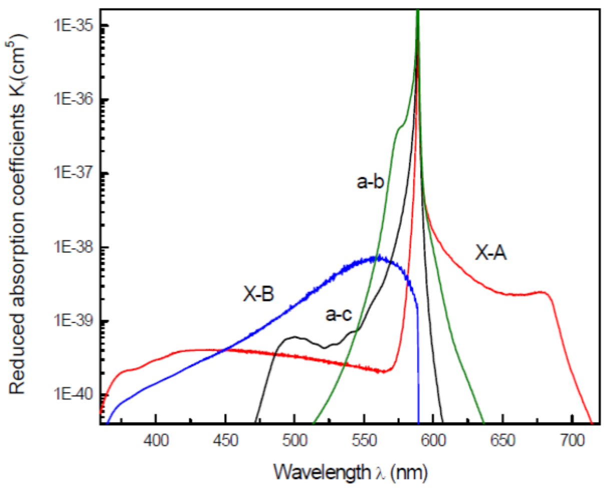

Figure 1 : Contribution of different transitions to the *aLi* spectra

Chaotic behaviour of the CML model with respect to the state and coupling parameters

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The main aim of this paper is the study of dynamical properties of the Laplacian-type coupled map lattice induced by the logistic family on a periodic lattice in dependence on two parameters: the state parameter of the logistic map and the coupling constant. For this purpose, tools like approximate entropy, maximal Lyapunov exponent, and the 0-1 test for chaos are introduced and applied to numerical simulations performed using a supercomputer.
Keywords: CML model; Approximate entropy; maximal Lyapunov exponent; the 0-1 test for chaos

Microwave oven plasma reactor moding and their detection

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Over the last 20 years microwave power supplies in domestic microwave ovens have increasing found applications in plasma reactors for processing of carbon-based nanomaterials. However, the packaged magnetrons used in the microwave ovens are known to suffer from moding due to frequency pushing and pulling, both of which may limit the efficiency of the plasma treatment process [1]. This paper explores patent records for high voltage doubler circuits, coupled to the cathode filament heater circuit as the magnetron pushing source and the multimode resonant cavity plasma load as the pulling source. These circuits are compared with microwave oven plasma reactor circuits published in peer reviewed journals.
This study reveals that a number of academic research groups have investigated power supply design parameters such as the input transformer voltage as well as the power level using different capacitors values at the transformer output are poorly described in a systematic way. However, identification of moding within the plasma reactors due to magnetron warm-up time and changing cavity load conditions is poorly reported. This work attempts to address this information gap on

microwave oven plasma processes, through the extraction of reports on a packaged magnetron warm-up times and near-field E-probe mode measurement within the Cambridge Fluid Systems MRC 200 plasma reactor as a function of working gas compositions of (argon and hydrogen) [2].

Key words: microwave oven, drive circuit pushing, load pulling, plasma

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Stochastic Motion of Tagged Particles in a Bath Responding to External Fields

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The description of the stochastic motion of a Brownian particle by the generalized Langevin equation (GLE) is extended to the case when the surrounding particles respond to external force fields. First, it is shown that, as distinct from the Kubo's derivation of the second fluctuation-dissipation theorem (FDT), the FDT holds also in the case when the random force arising from the particle environment, and thus also the memory function G(t), both depend on the external force. Such a modified G(t) is derived within a generalized Caldeira-Legget model for a tagged particle in a bath of harmonic oscillators. The system is placed in an external harmonic potential, and, for charged particles, in static or oscillating electric and magnetic fields. Modified equations of motion of the bath particles lead to new GLEs for the tagged particles with memory functions affected by the applied fields. Along with the proof of ! the validity of the FDT for stationary systems, the velocity autocorrelation function and other relevant correlation functions have been derived. To proceed with the explicit calculations of these functions and with the full description of the Brownian motion of the tagged particle, the theory must be supplemented by a model of the spectral density of the oscillators' frequencies. Several such models are discussed, in particular, the Drude model that in the absence of the bath response to the external fields determines the memory function that exponentially decreases in time. The obtained results could be important for a number of studies related, e.g.,

to the Brownian motion in a confining potential or to a stochastic motion of charged particles across a magnetic field.

Keywords: Brownian motion, Generalized Langevin equation, Bath of oscillators, Response to external fields, Fluctuation-dissipation theorem

Prediction Model of Microstructure Evolution and Fatigue Crack Propagation Behavior of Superalloys in Service

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The current research published about fatigue crack growth behavious mostly focused on the effect of external environment and loading conditions but little on that of microstructure evolvement, concerning this issue, the microstructure evolvement and fatigue crack growth rate (FCGR) of GH4169 alloy after long-term aging was researched in this paper and the micromechanism of microstructure reflecting on FCGR was also analyzed. It is found that the GH4169 alloy has good microstructure stability and has not exhibited apparent microstructure changing during long-term aging at 650℃. The size of both γ′ and γ″ phase increased, while the total volume fraction of them kept almost constant with the increasing of aging time. δ phase precipitated in the shape of granules or short bars, mostly on the grain and twin boundaries and some inside the grains, which increased in amount but kept in the same size.! The FCGR test was carried out for the specimens after different aging treatments, and the fractograph was examined. The results shows that the FCGR increased slightly with the increasing of aging time at 650℃, inconspicuous in Paris region and more obvious in near-threshold region and fast propagation region. Besides, when the alloy was long-term aged at 750℃, the FCGR increased evidently with the increasing of aging time, while the fatigue crack growth threshold decreased. It is considered that the coarsening of γ′ and γ″ phase long-term aged at 650℃ and the transition from γ″ phase to needle-like δ phase at 750℃ which degraded the strength and weakens the crack closure effect and crack tip stress shielding effect should be blamed for the decreasing of fatigue crack growth resistance and consequently, the increasing of FCGR. The crack closure effect is mainly induced by roughness, while the crack tip stress shielding effect is caused by crack branching i! n this research.

Keywords: Chaotic modeling, Simulation, Superalloy, Microstructure, Fatigue crack propagation behavior.

Sunspot in the Chamley Optimal Control Model

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In this paper we consider the Chamley (1993) model, a two-sector model with an implicit characterization of the learning function. Bella and Mattana 2014 have shown that under some ‘‘regularity’’ conditions regarding the learning function, the model has (a) one steady state, (b) no steady states or (c) two steady states (one saddle and one non-saddle). In our formulation, we are able to construct sunspot equilibria in a determinate parameter set where there exists a homoclinic orbit (the two-dimensional manifold is well located in an ambient space). We confirm that, as shown in literature, the construction of rational sunspots equilibrium comes from indeterminacy globally results. In other words, it could be done as a randomization over different equilibrium trajectories or equilibria, (as closed orbits).
Keywords: Multiple steady states, sunspot, Homoclinic cycle, indeterminacy
Cycle and Complex Dynamics in Economics models
We are interesting in topics related to chaos and cycles in Economic-financial models.

Detection of Crossing/Sliding Regions and their Sets of Attraction in Non-Smooth Dynamical Systems

Luciano Lopez
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In this talk we consider differential systems of Filippov type, i.e. of the form: $x'=f(x)$, where f is discontinuos when the solution x(t) meets a surface Σ defined by $h(x)=0$. That is $x'=f_1(x)$ when $h(x)<0$ while $x'=f_2(x)$ when $h(x)>0$. On Σ the vector field will be given by the Filippov sliding vector field.
It is important to find regions of the phase space for wich starting with initial points in these regions we reach the crossing or sliding regions for such a discontinuos system.
We will study computational methods to locate crossing/sliding regions on Σ, to compute the sets of attraction of these regions together with the mathematical form of the separatrices of such sets.

This is a joint work with: A. Colombo (Politecnico of Milan) and N. Del Buono and A. Pugliese (Department of Math, University of Bary, Italy).

A Chaotic Figure Drawing Method and System

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Exposure to hand-drawn gestural figure drawings led to the hypothesis that a nonlinear dynamical model could be used to create algorithmic art incorporating elements of human skill and chaotic motion. Based a simulation approach developed by the author to study mathematical models of an extrinsic photoconductor at Harvard in the 1980s, a method was developed to translate hand-drawn images of people (quick gestural sketches of typically unclothed bodies done in ink) into a potential function and thence, via chaotic simulation, into a variety of chaotic images. The system was subsequently enhanced to allow photographic and video images to be translated (via computerized edge detection) into line “drawings” and then into chaotic still or moving images. The method allows novel types of algorithmic visual art to be created.
Keywords: Chaotic modeling. Image processing. Edge detection. Potential Functions. Non-linear dynamic system. Chaotic Simulation. Visual art. Figurative Art. Algorithmic visual art

Traveling waves and space-time chaos in excitable media

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It will be shown, that the FitzHugh-Nagumo type system of partial differential equations with fixed parameters, describing the excitable media, can have an infinite number of different stable wave solutions, travelling along the space axis with arbitrary speeds, and also traveling impulses and an infinite number of different states of space-time (diffusion) chaos. These solutions are generated by cascades of bifurcations of cycles and singular attractors according to the Feigenbaum-Sharkovskii-Magnitskii (FShM) theory in the three-dimensional system of ordinary differential equations, to which the FitzHugh-Nagumo type system of equations can be reduced by self-similar change of variables. Examples of the application of the theory to the description of processes of chemical and biological turbulence will be considered.
Keywords: Excitable medium, Traveling waves, Impulses, Space-time chaos, FShM-theory

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Scaling features analysis of the Internet Interdomain Routing data sets

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In present work we aimed to investigate time series of BGP updates from 4 autonomous system (ASes). Main research task, we targeted, was to learn how scaling features of the process of BGP updates is changing over considered period. Exactly we analyzed BGP updates time series from 07.07.2011 to 23.11.2011. In order to assess scaling features of BGP updates time series we have used method of Detrended Fluctuation analysis (DFA). DFA analysis has been accomplished for sliding windows of different length. Additionally we have carried out similar analysis for sliding windows in which BGP updates process by other analysis, using different data analysis methods, was recognized as regular and/or random-like. We found, that the process of BGP updates variability, though is very specific for each of 4 considered data sets, still reveals similarity in the scaling properties of behavior during the analyzed period.

Exactly we found that all 4 BGP update data sets reveal persistent behavior what was confirmed for sliding windows of different length. This may point about global character of unknown influences on the behavior of BGP updates. Additional analysis of windows in which the process of BGP updates was recognized as regular indicated that in these windows DFA scaling exponents often are closer to complete persistence while in windows recognized as irregular prevailed less persistent and antipersistent behavior.

Keywords: Autonomous systems, BGP updates, Dynamics, scaling, complexity

Cystoseira vs Turf Algae: Inter-Algal Competition via Population Dynamics Model with Pack Behaviour

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The co-existence of the alga Cystoseira and microalgae forming the turf, is described through a simplified trophic web including the algae as two different species in competition for light, nutrients, soil availability, plus sea urchins consuming them. The choice is to write a space-implicit model of ordinary differential equations (ODE) describing the evolution of two population biomass: of Cystoseira, C and of turf algae, T. The two populations show different recruitment mechanisms. The gametes of turf microalgae are brought by sea currents and continously raining on the sea bottom; hence the recruitment contribution of dT/dt is constant flow independent on the respective populations. The propagules of Cystoseira can only travel a very short distance away from the mother alga; moreover, propagules falling within the canopy forest cannot root: Cystoseira rectuitment happens only slightly outside the border of the canopy forest, and its value must be rather proportional to the Cystoseira biomass laying there. In a space-non-explicit model, this purely border effect leads to a recruitment term in dC/dt proportional to C^(1/2). The prescription of being a growing function of the square root of biomass, mathematically the same as the pack behaviour of populations interacting only through their border, is applied to all the growth or decrease terms representing processes taking place just along the borders of populated areas (e.g., the Cystoseira consumption due to sea urchins, because these invertebrates only browse along the border of the canopy forest, or the expansion of turf algae living along the turf border).

Keywords: Trophic webs, Pack behaivour, Inter-algal competition, Simulation

Stabilisation of Nonlinear Viscoelastic Fourth-order Problem Algeria

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In this talk we will investigate the stability of the nonlinear viscoelastic problem governed by bilaplacian operator. We denote by Ω an open subset of 〖 R^n with regular boundary Γ. Let Q the cylinder 〖 $R_x^n \times \mathbb{R}_t$ with $Q = \Omega \times]0,T[$;
T fini, Σ boundary of Q, u_0 (x)and u_1 (x) are functions. We look for the stabilisation of a function u = u(x,t), x ∈ Ω, t ∈]0,T[, solution of the problem (P).
(P){((∂^2u)/(∂t^2)-Δ^2 u+$\int_0^t$g(t-s)Δu(s)ds=f in "Ω" x]0,T[@u(x,t)=Δu(x,t)=0 on "∑" @u(x,0)=u_0 (x),∂u(x,t)/∂t $_{|(t=0)}$=u_1 (x) x∈"Ω" @)┤

Keywords: Fourth-order,Nonlinear,Priori Estimate,Stability,Viscoelastic

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Investigation of chaotic instabilities in railway wheel squeal

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The occurrence of chaotic motion in a railway instability phenomenon known as wheel squeal is investigated. The analysis is motivated and applied to predicting the large amplitude friction excited oscillations of the coupled wheel and rail motion. The equations of motion reduce to two autonomous coupled nonlinear second order systems. Instabilities of the wheel and rail motions are shown to be due to the friction coupling which at low amplitudes causes limit cycle behavior via a Hopf bifurcation. When the amplitude grows large enough, full nonlinear creep oscillations are shown to occur causing oscillations about positive and negative sliding conditions. Chaos is shown to occur when the motion meanders close to two distinct limit cycle solutions and is characterized by a Poincare map with fractal nature. The onset to chaos is shown to be via intermittency. Conditions under which chaotic instability is more likely to occur such as wheel and rail dynamic parameters are identified and discussed. The results may describe why some very load occurrences of wheel squeal are not characterized by a pure tone.
Keywords: Chaotic motion, Railway wheel squeal, Hopf bifurcation, Poincare map

Evolution equations for probabilistic characteristics of Lévy-type processes

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A wide class of processes arising in various areas of natural sciences and economics are mathematically stated in the form of stochastic differential equations (SDE) with random perturbations described by Wiener, jump, and stable processes, in general, Lévy-type processes. One of the important directions in the study of such problems is the investigation of the connection between stochastic equations and deterministic equations for probability characteristics of solutions to the SDE considered. In contrast to diffusion processes corresponding to Wiener perturbations and connected to partial differential equations for probabilistic characteristics, Lévy-type processes are associated with integro-differential (pseudo-differential) equations for probabilistic characteristics.

The question under the discussion is 'How the integro-differential equation corresponding to the given SDE can be derived?' We consider three ways to achieve this goal.
The first approach is based on a generalization of the Ito formula for the Lévy-type processes [1]. As a result we obtain a backward equation for a certain type of probabilistic characteristics.
The second approach goes back to the ideas of A.N. Kolmogorov and relies on the first and second orders local moments of the process, as well as on the (dis)continuity properties of its trajectories [2]. In the framework of this approach, both direct and backward integro-differential equations can be obtained for various probabilistic characteristics of some processes important in applications, and transition probability density is one of these characteristics.
Finally, the third approach is connected with semigroups of operators, Fourier transform, and the Lévy-Khinchin formula. It allows one to get the generator of the considered process, which is the same as the generator of the transition semigroup [3], and get the sought equation.
Keywords: Lévy-type process, Ito formula, Markov process, transition probability, semigroup of operators.
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Symplectic local Lyapunov exponents occur in pairs

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Chaos in Hamiltonian systems is special. For example, the global Lyapunov exponents of Hamiltonian systems occur in pairs (λ,-λ). For local Lyapunov exponents, whose time averages converge to the global Lyapunov exponents, the pairing property depends on the method used to calculate the local Lyapunov exponents. While local Lyapunov exponents of Hamiltonian systems calculated via the QR method do generally not have the pairing property, we show that the so called symplectic local Lyapunov exponents occur in pairs. Hereby, the symplectic local Lyapunov exponents are defined using the Iwasawa decomposition of the real symplectic group Sp(2n). We explain, why for chaotic Hamiltonian systems it is more appropriate to use this

decomposition than the QR decomposition, and we provide numerical examples.

Keywords: Chaotic Hamiltonian systems, Symplectic Group, Local Lyapunov Exponents, Iwasawa decomposition, Numerical calculation of Lyapunov exponents

Stick motions occur on two mass impact system with forced vibration based on a pair of gears

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Gears are implemented into many machines as essential parts for power transmission. Backlash is a clearance between mating gear teeth, and it is necessary for the smooth operation of the gears to optimally setting the backlash. However, when external force is applied, impact oscillation occurs in gear systems under some conditions. As an example of impact oscillation, there is a gear rattle during car idling. The gear rattle is caused by tooth surface separation due to torque fluctuation of the engine when the steady torque is small. The gear rattle is cause of engineering problems such as gear noise and galling. In order to solve these problems, it is important to investigate the origins of a stick motion that arise on the teeth of gears. In the stick motion, since two teeth move together and do not collide, it is thought that the gear noise and galling hardly occurs.

In this paper, we investigate the cause of the stick motion. First, numerical simulation is performed using model proposed by Luo and others [1] to confirm that the properties are the same as the experimental result. Next, we analyze the system behavior when frequency of external force is changed. Note that, the left and right gaps are by Dd, (1-d) D respectively, using the ratio D and the total clearance d. As a result, we found some properties to induce stick motion.

Keywords: impact vibrating system, bifurcation, gear, stick.

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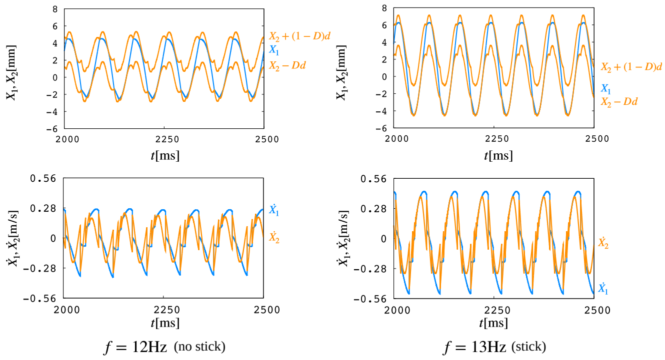

Fig. 1. Time series waveform (d=3.5mm, D=0.05).

Determination of Nonlinear and Strongly Correlated Parameters Characterizing the Complex Systems

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To describe quantitatively the growth of biological systems, the data-at-age are fitted by making use of the time-dependent functions including the parameters to be determined by numerical procedures. Among numerous mathematical models applied in the growth analysis the most popular and frequently applied is the von Bertalanffy (VB) function. It depends both on linear and nonlinear parameters whose simultaneous determination produces unstable (divergent) fits when parameters are freely adjustable. To avoid this problem the method of scanning of the n-exponent of the VB function is employed. In this approach n is treated as constrained parameter which changes with the step 0.001 in the range 0 ≤n < 1 and remaining parameters are determined together with normalized standard deviation NSD (n). The rough values of parameters defining minimum of NSD (n) are applied then as the initial values for the fitting procedure with all freely adjustable parameters. Such an approach permits obtaining complete statistical characteristics of the outputs including not only values of the nonlinear parameters fitted but also their standard errors, indicators of the goodness of the fit and the correlation coefficients. The test calculations revealed that: (i) the problem with the fit stability reported for the VB function is not connected only with nonlinear nature of the scaling n-exponent, but (ii) its main source is strong correlation of n with remaining parameters defining the model as well as (iii) n-value placed in the vicinity of the discontinuity point n = 1 or outside the standard range 0 ≤n < 1 usually applied in the data analysis. The method proposed is general and

can be applied in determination of strongly correlated parameters characterizing nonlinear processes in complex systems.

Keywords: Nonlinear dynamics, Pattern formation, Complex systems, Data analysis, Fitting procedure, von Bertalanffy model

Integrable nonlocal models

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A nonlocal nonlinear Schrödinger (NLS) equation was recently introduced in Phys.Rev.Lett. 110, 064105 (2013) and shown to be an integrable infinite dimensional Hamiltonian evolution equation. In this talk we present a detailed study of the inverse scattering transform of this nonlocal NLS equation. The direct and inverse scattering problems are analyzed. Key symmetries of the eigenfunctions and scattering data and conserved quantities are discussed. The inverse scattering theory is developed by using a novel left-right Riemann–Hilbert problem. The Cauchy problem for the nonlocal NLS equation is formulated and methods to find pure soliton solutions are presented; this leads to explicit time-periodic one and two soliton solutions. A detailed comparison with the classical NLS equation is given and brief remarks about nonlocal versions of the modified Korteweg–de Vries and sine-Gordon equations are made.

Chimera states, SQUIDs and Metamaterials

Design of steel fiber reinforced segment with curved radial joints

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Mumbai Metro Line 3 is major underground project with 33.5 km of twin tunnels and 27 stations with estimated cost of 2.8 million Euros. The tunnels are being constructed with tunnel boring machines (TBMs). Segments for this project have curved radial joints to minimize crushing of concrete during ovalisation and convergence of segmental lining. Curved radial joints have lower contact widths between segments resulting into higher stresses around area of contact. The existing guidelines do not provide a design approach for curved radial joints of steel fiber reinforced concrete (SFRC) segments. This paper discusses an approach to design radial joints for SFRC segments by combining International Tunnelling Association (ITA) guidelines and Roark's design formulas. The parameters considered for design are included and verified by test results. Likely future improvement in this design approach is optimizing amount of

reinforcement required for radial joints by considering tensile capacity of SFRC matrix.
Keywords: Tunnel, steel fiber, metro, segmental lining SFRC

Nonlinear integral transforms and laser dynamics

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The nonlinear integral maps are introduced as generalization of the Fox-Lee integral equation known from laser theory. This convolution of paraxial diffraction Huygens-Fresnel integrals and point iterative maps of Feigenbaum and Ikeda types is equivalent to nonlinear partial differential equation. The examples of exact eigenmode solutions of optical cavities corresponding to Fresnel number N_f ranging from 1 to ∞ are presented. The dynamical regimes of these time-delayed integral equations comprise single spatial mode and multimode spatial patterns including temporal chaos, spatially periodic Talbot patterns, vortex lattices, stable and unstable soliton-like eigenmodes of $sech$-form, kinks and dark solitons.
Keyword: Discrete maps, integral transforms, solitons, vortices, switching fronts, periodic solutions, vortex lattices, chaos, turbulence, effective magnetic fields, probability.
density.

Magnetospheric chaos and dynamical complexity response during storm time disturbance

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In this work, we have examined the magnetospheric chaos and dynamical complexity response in the disturbance storm time at different enhancement of geomagnetic storm. The dynamics of the Dst signals was categorized as minor, moderate and major geomagnetic storm based on the intensities of the Dst index. Each month Dst index time series was analyzed for the period of nine years using nonlinear dynamics tools such as Maximal Lyapunov Exponent (MLE), Approximate Entropy (ApEn), and Delay Vector Variance (DVV) method. Our analysis shows a noticeable trend between minor, moderate and major geomagnetic storm. The MLE and ApEn indicate a high chaotic and dynamical complexity response

during minor geomagnetic storm. At moderate geomagnetic storm, the response of chaos and dynamical complexity reduces with further reduction as the influence of geomagnetic storm intensified. In addition, the results obtained from DVV analysis reveal that as the influence of geomagnetic storm increases, the degree of nonlinearity builds up. Based on our findings, the dynamical information obtained through nonlinear dynamics suggests a useful characteristic to detect the influence of geomagnetic storm.

Keywords: chaos, Dynamical complexity, Maximal Lyapunove exponent, Approximate entropy, Geomagnetic storm.

On the universality of the normal law and some connected problems useful in the chaotic and complex systems analysis

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In this paper we shall refer in short to some problems regarding to the normal distribution law. Thus, the limit theorems and limit laws in probability theory will be discussed firstly. Also we shall refer, shortly to some variants of the limit theorem due to De Moivre and Laplace. On the other hand, it is known that the Central Limit Problem in Probability Theory is the problem of laws of convergence of sequences of sums of random variables. It appeared due to a new approach by Paul Lévy of the classical limit problem. Lévy formulated and solved the following problem: find the family of all possible limit laws of normed sums of independent and identically distributed random variables (in brief i:i:d:). In this context we shall refer firstly to the first limit theorem of probability theory due to Jacques Bernoulli; then, to the second limit theorem obtained initially by Abraham DeMoivre in 1730, for $p = q = 1/2$ and then generalized by Pierre Simon de Laplace for $0 < p < 1$; and finally we discuss about the third limit theorem found by Siméon Denis Poisson. In the last part we shall refer to some aspects which emphasize the universal character of the normal law,

Keywords: random variable, limit theorems, normal distribution law, convergence

An approach to supergranulation through its parameters

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Supergranulation is examined through its various parameters such as Area, perimeter, circularity and fractal dimension. A connection amongst these parameters throws light on the turbulent aspect of this convective feature. Area and perimeter at various latitudes are also studied in detail. The spread shows an asymmetric dispersion with a minimum dimension at around ±25º because there is a theoretical calculation which indicates that the enhanced fields will reduce the supergranular cell sizes (Chandrasekhar, 1961) around these latitudes. A much diverse approach gives an added insight into this finding.

Keywords: Sun; Granulation - Sun; Activity - Sun ;Photosphere

Least-order models for generic instabilities in fluid mechanics

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In this presentation, we propose least-order models for successive supercritical Hopf and pitchfork bifurcations in the "fluidic pinball" configuration, as a prototype for generic classes of instabilities encountered in fluid mechanics.

Influence of the Heart Rate on Dynamics of Cardiorespiratory System

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Laws of dynamics of the DeBoer's model of the cardiovascular and respiratory systems are studied taking into account dependence of parameters of a respiratory action on cardiointerval characteristics and variation of the heartbeat. The linear approximation of unknown functional dependences of feedback influence are investigated. By methods of the modern theory of dynamical systems the steady-state regimes of the modified models are studied. It has been shown that a reverse influence of parameters of a cardiosystem frequency on frequency of respiratory oscillations results in irregularity of the dynamic mode of the combined system, i. e. a cause of chaos appearances in the cordially-respiratory system is internal interaction of subsystems : cardiovascular and respiratory. A decrease in heart rate causes a decrease in pressure, which has also been found.
Keywords: Heart rate, Cardiovascular system, Respiratory system, Feedback, chaos

Regularity and Chaoticity in Hadron Spectra

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We report on studies of quantum-chaotic behaviour in hadron spectra. The investigations have been carried out along a constituent-quark model relying on a relativistically invariant mass operator. Mesons and baryons are considered as two- and three-body systems, respectively. The quark-(anti)quark interaction is furnished by a linearly rising confinement and a hyperfine potential deriving from the low-energy dynamics of quantum chromodynamics modeled by Goldstone-boson exchange. The excitation spectra exhibit quantum chaos with level spacings congruent with Wigner distributions according to a Gaussian orthogonal ensemble. In case of confinement only the spectra turn out to be regular, corresponding to a Poisson distribution. Similar results are found in case of the Dirac operator solved along lattice gauge theory. We consider hadron spectroscopy as a promising field for studying quantum chaos.

Keywords: Quantum chaos, hadron spectra, constituent-quark model, quantum chromodynamics

Lyapunov-Poincare equation and homoclinic chaos

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Represented report is devoted to obtaining the necessary and sufficient conditions of the existence of solutions of the following boundary value problem for the evolution equation

$$x'(t, e) = Ax(t, e) + eR(x(t, e)), \quad (1)$$

$$lx(. , e) = a + eJ(x(. , e), e), \quad (2)$$

where the unbounded operator *A* acts from *D(A)* (*D(A)* is dense subset in the Hilbert space *H*) into the Hilbert space *H; R, J* are smooth nonlinearity, l is a linear and bounded operator which translates solutions of (1) into the Hilbert space H_1. We find solutions of the boundary value problem which for e = 0 turns in one of solutions of generating problem. We obtain sufficient condition of the existence of homoclinic chaos with using of the equation for generating elements which in periodic case coincides with the well-known Lyapunov Poincare equation for generating amplitude [1] and Melnikov function [2], [3].

Keywords: Chaotic modeling, Moore-Penrose operator, generalized inverse operator

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A Dynamical Model for Plasma Fireball

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The elementary atomic collision processes, like excitation, ionization or recombination, taking place in a plasma system play an essential role in the appearance of instabilities. They are generically called reactions and, together with diffusion, processes that can be coupled only far from the thermodynamic equilibrium, can serve a basis for explaining the emergence of self-organized spatial structures. One example is the fireball, extensively studied experimentally, both for deciphering its formation mechanism and for studying the peculiarities of the mutual interaction of two or three such entities. Basically, an electric field applied to plasma formed in a DC plasma diode drives the system outside its thermodynamic equilibrium. If this electric field surpasses a certain threshold value, a so-called diffusion driven instability (or Turing instability) is triggered, at the end of which a plasma fireball is self-assembled at the surface of the anode, the current density jumping to a much higher value than below the threshold. The system behaves strongly nonlinear and the observed phenomena can be explained by considering collective effects of quantum reaction processes enumerated above, as well as the diffusion of the involved plasma particles with different values of their diffusion coefficients. From this perspective, a plasma fireball can be regarded as an example of Turing structure. The purpose of the present work is to present some results of the mathematical modeling of a plasma fireball, treated as a Turing structure. Earlier results, using an electric circuit model, proved that the fireball is indeed a Turing structure, belonging to the same type as the Brusselator (the famous prototype of Turing structures in Chemistry). The obtained results with the help of the circuit model allowed to set the conditions which the negative differential resistance (related to the self-assemblage of the fireball) must satisfy for the emergence of such a structure on the anode of a plasma diode. On the other hand, in the frame of the present model, by considering the relevant elementary reaction processes taking place in front of the anode of a plasma diode, when the fireball is formed, a new set of conditions are found, relating the neutral concentration and the ionization, respectively recombination reaction rates that allow the appearance of the fireball.

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Keywords: plasma fireball, Turing instability, reaction-diffusion system, dynamic model

Nonlinear Dynamics of Complex Space Charge Structures at the Origin of Low-Frequency Plasma Instabilities

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Local self-structuring of plasma in the form of complex space charge structures (fireballs, multiple double layers, plasmoids, plasma bubbles, etc.) is a well known phenomenon. The local balance between the generation of charged particles (positive ions and electrons), mainly by ionization electron-neutral collisions, and their losses through recombination and diffusion, ensures the stability of such structures. In conditions where this equilibrium cannot be maintained, such a complex structure passes into dynamical state, consisting of periodic aggregations and disruptions of the double layer existing at its border. During the disruption phase, bunches of electrons and positive ions are periodically injected into the surrounding plasma, triggering low-frequency instabilities that manifest as oscillations of the plasma parameters (plasma potential, electron and ion densities). By recording and analyzing the time series of these oscillations, we can obtain information about these instabilities. In certain experimental conditions, chaotic states of plasma can be achieved through different scenarios.
Acknowledgment: This project is funded by the Ministry of Research and Innovation within Program 1 Development of the national RD system, Subprogram 1.2 Institutional Performance RDI excellence funding projects, Contract no. 34PFE/19.10.2018. Also, this work was supported by a grant of the Ministry of Research and Innovation, CNCS-UEFISCDI, project number PN-III-P4-ID-PCE-2016-0355, within PNCDI III.
Keywords: Instability, Double layer, Fireball, Chaos

Waves in Large Disordered Anisotropic Fractal Systems, in Clusters of Drones or Small-Size Space Vehicles, in Synthesized Space Antenna Aggregations, and in Radiolocation

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The up-to-date status of researches in the problems of non-single scattering of waves by fractal discrete random media is presented. The non-single scattering theory for waves in media containing random scatterers has been learned by many authors [1-8]. In case of statistical consideration of waves scattering they base on the stochastic wave equation or on a system of such equations which the problem of wave's diffraction on a statistical ensemble is investigated and formulated for. Although all these researches led to discovery of some basic physical principles there are still many problems concerned the non-single scattering in fractal media. Issues of the general theory of non-single scattering of electromagnetic waves in fractal random media on the basis of the Foldy-Tversky classical theory modifications are considered in detail [1-3]. A designed modification of the non-single scattering theory allowed including values of fractal dimension D and fractal signature $D(\mathbf{r}, t)$ of disordered large system into consideration The radar equation has been analytically considered for an extremely fractal medium. Theoretical researches are agreed with previously published results of foreign authors [4, 7]. Similarly, one can prove the solution for anisotropic irregular fractal systems: fractal cascades enclosed to each other, graphs of fractal chains, percolation systems, space rubbish, clusters of drones or small-size space vehicles (SSV) including mini- and micro- classes, dynamical synthesized space antenna aggregations (cluster apertures), space-distributed cosmic systems (clusters) from small SSV for solving problems of emergency monitoring and so on. This research continues the author's series of papers on justification of application of the fractal theory, physical scaling and fractional operators in issues of radio physics and radiolocation.

Keywords: Fractals, Waves, Non-single scattering, Fractal regimes, Radiolocation, Small-size space vehicles, Clusters of drones, Clusters of small-size space vehicles, Dynamical synthesized space antenna aggregations.

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40 Years of Work with Textures and Fractals for Development of New Informational Technologies

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Scientific directions and author's main obtained results on designing of new informational technologies basing on textures, fractals, fractional operators and dynamical chaos are presented in the work. The research is conducted in the framework of scientific direction “Fractal radio physics and fractal radio electronics: designing of fractal radio systems”, which was proposed and being developed by the author in the IRE V.A. Kotelnikova RAS from 1979 to the present. Introduction of the conceptions above into the scientific usage of radio location allowed the author to propose for the first time in the world and then to apply new dimensional and topological (not power!) signs or invariants, which are united under a generalized conception «sampling topology» ~ «fractal signature» [1-5]. The results of A.A. Potapov’s scientific efforts on the fractal and textural processing of information in the presence of high-intensity noise, and also on fractal radio systems and fractal radio elements are published in summary reports of Presidium of Russian academy of science (RAS) (Scientific achievements of RAS. - M: Nauka, 2008, 2010, 2012 and 2013) and of the Report to the Government of the Russian Federation (2012). All these world priority results allow to move on the new level of information structure of the real non-Markov signals and fields. The fulfilled researches have high priorities in the world and serve as a basis for the further development and substantiation of application of fractal-scaling and textural methods in the modern radio physics, radio location, nanotechnologies and also in creation of brand new and more accurate fractal-textural (topological) methods of detection and measuring of radio signals' parameters in the space-time radar channel of radio waves propagation with scattering.
Keywords: Waves, Fractals, Textures, Fractal regimes, Fractal detector, Radiolocation.
Acknowledgment *This work was supported by the RFBR, project no. 18-08-01356, and by the “Leading Talent Program in Guangdong Province” program at the Jinan University (China, Guangzhou), project no. 00201502, 2016–2020.*
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Well posedness of a fractional Klein–Gordon Schrodinger system

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In this paper we consider the following Cauchy problem of a dissipative Klein Gordon Schrödinger type system with different order of fractional operators (FKGS for short) through Yukawa coupling in one space dimension

$$\begin{cases} iu_t + (-\Delta)^{b_1} u + iau = uv, \\ v_{tt} + (-\Delta)^{b_2} v + v + \lambda v_t = -\operatorname{Re} u_x, \\ u(x,0) = u_0, \\ v(x,0) = v_0, v_t(x,0) = v_1 \end{cases}$$

Using Strichartz 1 dimensional estimates we prove the local well posedness of the system. Based on this result and with the help of a priori energy estimates we prove the global well posedness.

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The associative memory based on the synchronisation effect of the Chua's circuit

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The scope of the work is to create the hardware of associative memory for onboard control systems of micro-robots. Widely used artificial neural networks (ANN) are hardware-independent implementations on analogue or digital bases. High level of abstract leads to heavy spend of hardware resources. Consequently, it leads to some difficulties with constructing power-efficient and small-sized ANN-based control systems for microrobots. The main idea of an approach used in this work is to build an ANN on the base of special artificial neurons. Many researchers have developed the approach. The bottom line is to use coupled Chua's circuits as neurons. First of all, the Chua's generator is a generator from the physical point of view since it operates not only with voltages but with currents too. Moreover, the approach utilises the effect of synchronisation between coupled Chua's circuits. To conclude, the associative memory developed in this work is a hardware implementation of the ANN. The dynamics of the memory depends on the low-level part of circuits such as capacitors, resistors and inductors. As a result, it is expected to achieve a high speed of parallel processing of a huge number of hardware neurons. The architecture of memory is supposed to build a miniature control system based on biological principles.

Keywords: associative memory, artificial neural network, chaos, Chua's circuit, microrobot

The Structure of Chaotic Attractors of Oscillators Chaotic Oscillations, containing dambed Oscillations

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The structure of chaotic attractors of two bistable dynamic systems whose oscillations contain damped oscillations is considered. The attractors of each of these systems consist of a pair of quasi-conical regions of attraction of phase trajectories, each of which is a stack of spirally folded two-dimensional manifolds, near which the phase point spirally moves in the direction from the top to the base of the cone.
Keywords: dynamic chaos, attractor, dynamic system, structure of chaotic attractor, damped chaotic oscillations.
1. Chaos and Nonlinear Dynamics
Chaotic models and attractors

Probalistic Rotational Dynamics in Dynamical Systems with Chaotic Compositional Multiattractors

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The technology of construction of chaotic multiattractors with tunable composition structure allows to realize new dynamic effects. One of them is the organization of the cyclic displacement of the region of localization of the motion in the phase space of a dynamical system multiattractor due to the probability asymmetry of transitions of the phase point between adjacent local attractors.
Keywords: heterogeneous multiattractor, compound multiattractor, compositional multiattractor, chaotic attractor, replication operator, dynamic system, probabilistic rotational dynamics.
1. Chaos and Nonlinear Dynamics
Classical Deterministic Chaos

Multiattractor Hyperchaotic System with a Small Perturbation of the Phase Trajectories

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A simple autostochastic dynamic system with a 4-dimensional hyperchaotic multiattractor is presented. The dynamics of the system differs from known analogs by small perturbation of the phase trajectories during transitions between local attractors.
Keywords: hyperchaos, compound multiattractor, hyperchaotic attractor, replication operator, dynamic system.
1. Chaos and Nonlinear Dynamics
Chaotic models and attractors

Composite Multiattractor Consisting of Attractors Rossler

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The dynamic system, the motion of which takes place on a 2-dimensional composite multiattractor consisting of Ressler attractors, is considered. The formation of a multiattractor is provided by the introduction of a replicating operator into the Ressler system containing the operation of mutual displacement of adjacent phase cells containing copies of the Ressler attractor. The displacement is used to combine the regions of attraction of chaotic attractors at the boundaries between neighboring cells.
Keywords: Rossler attractor, compound multiattractor, replication operator, dynamic system, phase cell
1. Chaos and Nonlinear Dynamics
Chaotic models and attractors

Homology and multifractal features of chaotic dynamic systems

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The peirodic nature of trajectory passing through a phase space is reconstructed using topological approach based on simplicial complexes, thus allowing a threefold approach in a addition to the dynamical aspect: algebraic, combinatorial and geometric. In this framwork we use several diferent simplicial complexes, such as neighborhood and clique complexes, enabling analysis from various different topological perspecticves. The most important characteristic of the simplex and the simplicial complex from the dynamical point of view is the volume. We show how volume of the simplex relates to the Hausdorff and correlation dimensions of the attractor and how other relevant multifractal features of the attractor may be obtained from the volume of the simplicial complex. We introduce sevaral simplical measures corresponding to the Sinai-Bowen-Ruelle measure and show how various topological invariants and oth! er measures of simplicial complexes may be directly related to the statistical and dynamical characteristics of the system under study, such as Lyapunov exponents, entropy etc. In particular we define topological entropy in genuinely topological terms based on the volume of simplicial complex, among other properties of the simplicial complex. Furthermore, we inspect the persistent topological features of simplicial complexes using homology and structure vectors of simplicial complexes and show how they reveal new dynamical, geometric and topological properties of dynamical systems which elude the standard approaches. Applications of this topological framework are illustrated on some of the well known chaotic attractors, such as Lorenz, Rossler and some of the attractors appearing in the fluid dynamics.

Keywords: Multifractality, attractor, chaotic systems, simplicial complex, persistent homology, structure vectors

Characterization of the Principal 3D Slices Related to the Multicomplex Mandelbrot Set

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This talk focuses on the dynamics of the different tridimensional principal slices of the multicomplex Multibrot sets. First, we define an equivalence relation between those slices. Then, we characterize them in order to establish similarities between their behaviors. Finally, we see that any multicomplex tridimensional principal slice is equivalent to a tricomplex slice up to an affine transformation. This implies that, in the context of tridimensional principal slices, Multibrot sets do not need to be generalized beyond the tricomplex space.

Keywords: Multicomplex Dynamics, Multibrot, Generalized Mandelbrot Sets, Airbrot, Metatronbrot, 3D Fractals, Tricomplex Space

Various Dynamical Regimes, and Transitions from Homogeneous to Inhomogeneous Steady States in Oscillators with Delays and Diverse Couplings

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This talk will involve coupled oscillators with multiple delays, and dynamic phenomena including synchronization at large coupling, and a variety of behaviors in other parameter ranges including transitions between Amplitude Death and Oscillation Death. Both analytic multiple scale and energy methods, as well as numerical results will be presented. Behaviors in both limit cycle and chaotic oscillators will be compared for various couplings. Finally, the effects of distributed delays will be considered for systems already treated using discrete delays, including bifurcation-theoretic results not available in the latter case.

Modeling of three fins (triangular, rectangular, semi-spherical) in heat transfer

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Thermal fins play a very important role in the field of heat transfer and fluid flow. The thermal conductivity, the thickness of the fins and the heat exchange coefficient influence the efficiency of the fins.
We studied heat transfer and compared the temperatures of three different types of fins. The comparison in thermal transfer between these three fins (rectangular, triangular, semi-spherical) allowed us to understand the effect of the geometry of the fin on the thermal behavior in the environment surrounding each fin to know the distribution the temperature in each point and the state of cooling of the wall.
In this sense, the semi-spherical fin gives the best results compared to the triangular and rectangular fins in terms of decreasing the temperature of the wall and maximum release of heat around the fin.

Modified Chaotic Circuit of the Van der Pol-Duffing

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In this paper realization of modified chaotic circuit of the Van der Pol-Duffing generator is presented. Modeling and research chaotic behavior as a function of a variable control parameter. The differential equations has been realized using commonly available op amps and the nonlinearity using diodes. The experiments indicate that chaotic behavior indeed emerges through the period doubling route as the parameter is changed.
Keywords: Chaos, Control, Generator, Micro-Cap

On best approximation theory

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Consider a self mapping T defined on the union of three subsets A,B and C of a metric space, T is to be called a tricyclic mapping if it satisfies T(A)⊆B, T(B)⊆C and T(C)⊆A. Taking inspiration from a recent work by the current authors. We shall discuss existence of best proximity points of tricyclic mapping in different subclasses of metric spaces. First, we introduce the notion of (S) convex metric space, thereby we acquire a best proximity point theorem for tricyclic contraction mappings. Afterwards, we study the structure of minimal sets of tricyclic mappings in the setting of Kohlenbach hyperbolic spaces, this way we obtain an existence theorem of a best proximity point for such mappings

Toxicological evaluation of the copper element in chronic insuficient subjects. In-vivo investigations by blood tests

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Renal insufficiencies are the result of chronic intoxications due to repeated and prolonged exposures to multiple harmful substances, in addition to unbalanced diet in addition to the consumption of tobacco, alcohol etc ...
All these factors lead to the onset of chronic renal insufusance disease which necessitates permanent hemodialysis by artificial ankle which carries out the purging of blood from the body through an artificial membrane based on copper.
With the aim of verifying the effect of copper in chronically insufficient subjects, we have tried, through our investigation, to make a toxicological evaluation of copper in these hemodialized subjects and compared them with the results of healthy subjects preselected in order to estimate the effects of copper on the health of dialysis patients because they spend an impressive amount of time (four hours per session at the rate of three sessions per week).
Keywords: Toxicological evaluation, copper, insufficient subjects, investigations, blood

Engineering of a Temperature Dependent Thermal Bath Coupled to a Biosystem

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In the emerging field of nanoelectronics, biosysystems have drawn in the past decade the attention of both experimentalists and theoreticians. Flexibility, programmability, and not expensive synthesis of biosystems make them the appropriate candidate for nanoelectronic applications. Biosystems can show different electrical properties. Therefore, the identification of the relevant charge transport channels in biosystems becomes a crucial issue. In the current study, the electronic transport through a biosystem in the presence of the environment is investigated. The environment is modeled as quantum oscillators coupled to the system. We have tried to consider the temperature effect explicitly in the system. In this regard, we have modeled the system as a double stranded tight-binding model with considering the spin degree of freedom for electrons. The system is in the contact of the left and right meta! l leads. On the other hand, the system immerses in a thermal bath. The oscillatory frequencies of bath vary with temperature. So, we can vary the bath parameters via the varying of the temperature. Here, we have tried to benefit the quantum chaos approach. Then, we have made the Hamiltonian matrix of system. We obtain the eigenvalues and eigenstates of the Hamiltonian matrix. The analyze is based on the statistical distribution of the energy levels. We have varied the temperature of the environment and investigate the stability properties of system. On the other hand, using the temperature dependent parameters, we can determine the charge transfer properties. We obtain the current-voltage characteristic diagrams for different temperatures of system and determine the system behavior. Therefore, one can study the electronic properties and temperature dependent response of system using the energy levels analysis through the quantum chaos tools. The obtained results determine! electronic behavior of a biosystem with respect to the tempera! ture.

Keywords: Quantum chaos tools, Nanoelectronic, Temperature dependent bath, Biosystem

Dynamics of a Cournot duopoly game with differentiated goods between public and private firms

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This paper investigates the dynamics of a nonlinear Cournot-type duopoly game with differentiated goods, linear demand and cost functions for two bounded rational players that have different objective functions. Specifically, the first player is a public company and cares about the social welfare and the second player is a private company which cares only about its own profit maximization. The game is modeled with a system of two difference equations. The stability analysis of the fixed points are analyzed and complex dynamic features including period doubling bifurcations of the unique Nash equilibrium is also investigated. Numerical simulations are carried out to show the complex behavior of the models' parameters. We show that a higher (lower) degree of the speed of adjustment and a lower (higher) degree of the parameter of product differentiation destabilize (stabilize) the economy. The chaotic features are justified numerically via computing Lyapunov numbers, sensitive dependence on initial conditions, bifurcation diagrams and strange attractors.
Keywords: Cournot duopoly game, Social welfare, Discrete dynamical system, Nash equilibrium, Stability, Bifurcation diagrams, Lyapunov numbers, Strange attractors, Chaotic behavior

The exact number of positive solutions for a class of quasilinear boundary value problems of type strong Allee effect

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By using the time- mapping approach we study the exact number of positive solutions for the following boundary value problem :

$$\begin{cases} -\left(\varphi_p(u^\alpha)\varphi_p(u')\right)' = \lambda f(u) & in\ (0,1) \\ u > 0 & in\ (0,1) \\ u(0) = u(1) = 0 \end{cases} \qquad (1)$$

Where

$\varphi_p(y) = |y|^{p-2}\, y, y \in \mathrm{R}, \alpha > 0, p > 1, a > 0, \lambda > 0 \; and \; f(u) = u^{p-1}(1 - u^{p-1})(u^{p-1} - a)$.

Problems of type (1) with p=2 occur in models. If α>0 this models a substance whose particles have a little movement if there are very few of them and whose diffusion velocity increases with the number of particles present in the space element, modelling for example flows through porous media. The case α <0 models a situation where particles have a very high velocity if there are few and a very low one if their density is large, thus modelling some effect of stickiness.

Keywords: p-Laplacian; positive solutions; quadrature method; strong Allee effect

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Determining Lyapunov Exponents of Acid Rains Time Series on Wet Rain Samples

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Chaos theory is a popular approach to detect nonlinear structure of the system. In most of the natural systems chaos is observable as last researches show us. Acid rain is important environmental problem with its negative effects. In this study, we aim that analyze the chaotic behavior of acid rains in Turkey with the chaotic defecting approaches. The data of pH degree of rain waters, concentration of sulfate and nitrate data of wet rain water samples in the rain collecting stations which are located in different regions of Turkey are provided by Turkish State Meteorology Service. Lyapunov exponents, reconstruction of the phase space, power spectrums are used in this study to determine and predict the chaotic behaviors of acid rains. As a result of the analysis it is shown that acid rain time series have positive Lyapunov exponents and wide power spectrums and chaotic behavior is observed in the acid rain time! series.

Keywords: Acid rains, chaos, chaotic analysis, Lyapunov exponents

Research of Atomic and Molecular Terms Chaotic

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This report is about creation of information models of light quantization and absorption by an atom and/or a molecule in a language alternative to the one-electron approach. For this purpose, the analysis of trigonometrical functions has been done which has revealed quantum numbers which have been applied to differentiating interpretation of the concepts "quantum"/"photon" and getting earlier unknown dependences for the terms of neutral atoms and diatomic homonuclear molecules. It has enabled to enter actual multielectronic classification of atoms and molecules. The idea of relative additivity of nuclear terms during formation of diatomic molecules has shown efficiency of the models obtained in such a way for multielectronic classification and systematization of optical functions and electronic structure of external shells of molecules.
Keywords: information models of radiation/absorption, alternative to the one-electron approach, signal of atomic and molecular terms.
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Butterfly Effects and Chaos within a Generalized Lorenz Model: New Insights and Opportunities

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Is weather chaotic? A view that weather is chaotic was proposed and is recognized based on the pioneering work of Prof. Lorenz who first introduced the concept of deterministic chaos. Chaos is defined as the sensitive dependence of solutions on initial conditions, also known as the butterfly effect. The appearance of deterministic chaos suggests finite predictability, in contrast to the Laplacian view of deterministic predictability. After a follow-up study in 1972, the butterfly effect has come to be known as a metaphor for indicating that a tiny perturbation such as a butterfly's flap may ultimately cause a large impact, such as the creation of a tornado. The two studies discussed above, as well as Lorenz's 1969 study, laid the foundation for chaos theory that is viewed as one of the three scientific achievements of the 20th century, inspiring numerous studies in multiple fields. Our daily experiences with weather predictions largely support Lorenz's view of a finite predictability. On the other hand, under some conditions, better predictability, as compared to the predictability limit documented within the scientific literature, has also been observed. For example, while some studies have suggested that a theoretical limit of predictability is two weeks, recent advances in supercomputing and high-resolution modeling technology (Shen et al., 2006; 2013) have yielded promising 30-day simulations for high impact weather systems (Shen et al., 2010). In a brief report highlighting remarkable simulations in 2011, Dr. Richard Anthes, former President of the University Corporation for Atmospheric Research (UCAR), proposed a visioning question: is the atmosphere more predictable than we assume (Anthes, 2011)? Since that time, the view of weather being chaotic has been revisited using newly developed Lorenz models (Shen, 2014, 2015, 2016, 2017, 2018; Fagh! ih-Naini and Shen, 2018). Recently, by conducting a comprehensive literature review (Shen et al., 2018a, b) and developing a new generalized Lorenz model (GLM, Shen, 2019), we (1) illustrate two kinds of butterfly effects in Lorenz's studies; (2) discuss various types of solutions (e.g., chaotic, linearly unstable, and nonlinear limit cycle solutions) in Lorenz models; and (3) propose that the entirety of weather is a superset that consists of both chaotic and non-chaotic processes. Depending on the time-varying collective impact of heating, dissipation, and nonlinearity, specific weather systems may appear on a chaotic or non-chaotic orbit with different predictability. A ten-year analysis of real world data using the newly developed parallel ensemble mode decomposition method (e.g., Wu and Shen, 2016; Shen et al., 2017) indicated the role of large-scale processes in providing a determinism for the small-scale processes. The revised view on the nature of weather suggests opportunities for obtainin! g longer predictability. To achieve this goal, methods with recurrence analysis and kernel principal component analysis have been implemented to detect and identify non-chaotic (as well as chaotic) processes within the GLM (Reyes and Shen, 2019; Cui and Shen, 2019).

Keywords: Chaos, Butterfly effects, Generalized Lorenz model, co-existence, recurrence analysis, kernel principle component analysis

Modulating the Light-Driven conductivity in a Biosystem

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Biosystems has been proved powerful for use in nanotechnology because of its predictable nanometer-sized structures. One important example is that we can use biosystems to develop the new two- and three-dimensional nanomachines and nanocircuits. To achieve this goal, people hope to control the conductivity properties of system. In this regard, light-regulated circumstances come into play. Photon-induced charge transport can regulate the conductivity properties of system. The role of photoresponse of π electrons of biosystems in light-driven conductivity theoretically studied. A model combined of classical Peyrard-Bishop-Dauxois and quantum tight-binding models is proposed for studying the photo induced charge transfer in DNA. A potential difference is applied to the system via the metal left and right leads and obtained the current-voltage characteristic diagram. In the current study, we have derived! the derivation equations of system and analyzed them through the chaos tools. We have varied the intensity and frequency of light and investigated their effect on the charge transport properties of system. Using the chaos tools, we can modulate the light properties for best charge transport in biosystem. Therefore, one can modulate the conductivity properties of system via the directly modulation of the light. The chaos tools can adjust the control parameters for improved charge conductivity.
Keywords: Chaos tools, light-driven conductivity, Photoresponse, Biosystem

Dual phase synchronization of chaotic systems using nonlinear observer based technique

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The present article reports an investigation on dual phase synchronization results among chaotic systems with nonlinear observer controller. The dual phase synchronization is achieved using nonlinear state observer technique and stability theory. Qi system and Newton-Leipnik system are considered during demonstration of dual phase synchronization. The nonlinear state observer technique is found to be very effective and convenient to achieve dual phase synchronization of various types of chaotic systems. Numerical simulation results for different particular cases are depicted through graphs to demonstrate the effectiveness of the control technique during dual phase synchronization among chaotic systems.

Keywords: Dual synchronization, Phase synchronization, Chaotic systems, Nonlinear state observer technique

Regular and Chaotic Attractors in System "Tank with a Liquid – Source of Excitation"

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Oscillations of the free surface of a liquid in a cylindrical tank excited by an energy source of limited power are considered. The mathematical model of such a system is a five-dimensional system of nonlinear differential equations. The case of vertical excitation a platform of cylindrical tank is investigated in details. The possibility of the emergence of several types of chaotic attractors of such a system is established. The scenarios of transitions from regular to chaotic attractors are analyzed. The symmetry of phase portraits and Poincare sections of both regular and chaotic attractors is described. We emphasize that the study of the dynamics of such a system without taking into account the source of excitation does not allow detecting chaotic attractors that actually exist in the system.

Keywords: tank with a liquid, regular and chaotic attractors, scenarios of transition to chaos, symmetric attractors

Influence of Delay on Chaotization of the Dynamical System "Generator - Piezoceramic Transducer"

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The nonideal dynamic system "analog oscillator - piezoceramic transducer" is considered at taking into account the delay factors. Two technics for construction of attractors of such system are proposed. It is shown that the delay can play the role of a kind of control action in the system "analog oscillator - piezoceramic transducer". Delay presence in considered system can essentially rebuild its dynamics. For example, regular, in the absence of delay, attractors of the system can become chaotic, in the presence of delay, and vice versa. Also, the consideration of the delay factors allows us to clarify the scenarios of transitions from steady-state regular regimes to chaotic ones and to describe new types of coexistence of regular and chaotic attractors.
Keywords: delay, regular and chaotic attractors, scenario of transition to chaos

The Effects of the Science of Chaos on Management Science

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The science of chaos has profoundly affected the basic philosophy and approaches of management science. Whereas management wishes to operate in a stable and orderly world, the reality is actually unstable and disordered. Emerging situation often catch managers by surprise, though they should accept uncertainty as the rule rather than the exception. This deeply affects how we understand change, growth, and innovation. Whereas, project management likes to plan on the basis of linear analysis, i.e., linear programming, predictable productivity, and Newtonian thinking, the real truth is non-linear and uncertainty. Thus, small changes in a multitude of areas from behavior to planning and logistics can have significant changes in outcomes, most of which cannot be foreseen. The

implications of the science of chaos on management approaches and philosophies are deep-rooted, revolutionizing the way we understand change, growth, and simple planning. Chaos theory helps understand in project management the uncertainties of cost analysis, linear analysis, and long range planning. Chaos also explains why our linear analytical thinking analysis often fails to deliver the right goods in project management, even though traditional planning requires linear thinking applications. Inasmuch as natural systems are chaotic and complex, so is human interaction in the workplace, which further intersects with the economy and world politics. Hence, the way to get past traditional management philosophies and embrace the complex management philosophies is to live at the edge of chaos, which anticipates change, creativity, and the incentive for advancement. It is better to flow with uncertainty than stand against it; it is better to be flexible and open-minded than have strong organizational cultures. Thus, dynamic instability, like chaos, is the real characteristic of evolving organizations. In fact, instability is necessary. More than that, without instability we would not have the world as we see it. Hence, this paper discusses the fundamental elements of chaos theory in its applications to understanding management and management science. The new face of this management science replaces the old and inflexible philosophies. It is, indeed, poised to be a new era in management science.
Keywords: Dynamic instability, Complexity, Non-linear paradigms, Uncertainty, Deterministic, Flexibility, Change, Innovation, Disorder

Theory vs Applications? Lessons Learned from First Exit Time Modeling

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Following my experience by editing and publishing numerous studies presented in the last 27 years I would like to summarize his experience in this presentation. Theoretical issues look to overcome the applied part of Stochastic Models. However, many theoretical advances came after specific needs emerged in the real life. A difficult task is to collect and store data in a way to support a related theory. Another point is to develop a flexible theory to cope with the provided data. To this end we present a

methodology combining theory and practice in Demography and especially in introducing stochastic modeling in human mortality and estimating the healthy life years lost. The results, after many years of work, support the importance of interconnection of theory and applications. Stochastic modeling is a quite strong tool for modeling real life applications, and real life provides enough variety in order to develop flexible applied stochastic models. Another challenge is related with transforming complicated stochastic models as to adapt to the data provided. And of course the interconnection with other scientific developments is extremely important. This is the case of Big Data modeling and artificial intelligence now at the core of scientific developments.
Few of the important parts of our work: When we used the first exit time theory to demography data sets an Inverse Gaussian was tested. Then the data directed us to an Advanced form of the Inverse Gaussian not included in the theoretical tools. In this case the application directed us to extend the existing theory. Another case appeared when applied a first exit time theoretical model based on a first order approximation. To improve application, we tried a second order theoretical model with poor results. The solution came by developing a fractional approach methodology for combining first and second order derivatives.
Finally, the combination of both theory and applications is of particular importance. No theory is ready to cover any application and the applications are needed to improve or develop theory; if good data exist.

Some Implications of Invariant Model of Boltzmann Statistical Mechanics to the Gap between Physics and Mathematics

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Some implications of a scale-invariant model of statistical mechanics to quantum nature of space and time and the physical foundation of mathematics are discussed. Kelvin absolute thermodynamic temperature is identified as a length scale associated with Wien wavelength $\lambda_{w\beta}$ of particle thermal oscillations ($kT_\beta = k\lambda_{w\beta} = m_\beta(v_{w\beta})^2$, $v_{w\beta} = \lambda_{w\beta}\ \nu_{w\beta} = \lambda_{w\beta}/\tau_{w\beta}$). Introducing interdependent *internal measures* of space and time called spacetime ($\lambda_{w\beta-1}$, $\tau_{w\beta-1}$) leads to independent *external measures* of space

and time ($x_\beta = N_x\lambda_{w\beta-1}$, $t_\beta = N_t\tau_{w\beta-1}$). Because of its *hyperbolic geometry*, its discrete fabric, and its stochastic atomic motions, physical space is called *Lobachevsky-Poincaré-Dirac-Space*. When physical space, Aristotle fifth element, Casimir vacuum, de Broglie hidden thermostat, or Dirac stochastic ether is identified as a compressible fluid, Planck compressible ether, Lorentz-FitzGerald contractions become causal, Pauli [3], leading to Poincaré-Lorentz dynamic as opposed to Einstein kinematic theory of Relativity [4]. Some implications of internal spacetime versus external space and time to relativistic effects in general and the "Time Problem" of GTR in particular will be discussed. Hierarchy of concentric spherical flows as exact solutions of invariant modified Helmholtz vorticity equation and their connections to Banach-Tarski paradox will be described. The role of iso-spin versus vorticity in connections to Schrödinger and Dirac wave equations are addressed. Finally, some of the implications of the model to Riemann hypothesis, analytical number theory, continuum hypothesis, infinitesimals, transfinite numbers, and Cantor's proof of higher cardinality of real numbers will be examined.

Keywords: Spacetime, Relativity, Quantum mechanics, Banach-Tarski paradox, TOE

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Deterministic irreversibility mechanism and basic element of matter

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The most important problems of physics on the way to build an evolutionary picture of the world include the following questions: how complexity arises from simplicity, how matter arises, whether there is a formalism that allows building a "theory of everything" [1]. For a long time, the main obstacle on the way to building an evolutionary picture of the world was connected with the fact that modern fundamental physics describes the existing world, but does not describe the processes of origin, evolution, and transformation of the world picture. This is explained by the fact that evolution is irreversible, but until recently, the mechanism of irreversibility was not known. Therefore, it was impossible to construct a physical evolutionary theory of the Universe. In the process of solution of the irreversibility problem, its probabilistic mechanism was proposed first. This mechanism was obtained basing on the condition of Lyapunov exponential instability of processes in Hamiltonian systems and the hypothesis of the existence of random external influences on them. However, since this mechanism of irreversibility was probabilistic, it did not answer the key questions: how order arises from chaos, how to build an evolutionary picture of the world, when the theory is based on probabilistic hypotheses. The recently obtained the determined mechanism of irreversibility (DMI) has eliminated these limitations [2]. DMI was found based on the mechanics of a structured particle (SP). In it, in the motion equation, instead of a body model in the form of a material point, the SP model was used, which is an equilibrium system from a sufficiently large number of potentially interacting MPs. The key conclusion that follows from the existence of DMI is the conclusion about the infinite divisibility of matter. It follows from the impossibility of the emergence of a structureless matter element within the framework of the laws of classical mechanics [7]. From this and from the fact of the existence of DMI is follows, then the basic element of matter should be an open non-equilibrium dynamic system (ONDS). In this paper, we will develop this statement. To do this, will be briefly describe the nature of DMIand how it existence helped to expand of the classical mechanics. Consider the principles of the emergence, existence and development of ONDS. We will study how external constraints determine the evolution of ONDS, which possible universal laws of behavior of the ONDS. We will determine the conditions under which the ONDS can be in stationary states and consider the ways of constructing the physics of evolution based on (ONDS).

Keywords: Entropy, irreversibility, determinism,evolution

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Constructive Redefinition of Extrema Concepts and Universal Method of Global Optimization

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Classical definitions provide not construction, but signs of extrema in usually multi-extremal real-world problems, mistakenly used by modern optimization methods, which prematurely stop an optimization processes and limit the degree of optimization and dimensionality of the problems being solved. The extrema constructivization consists in identifying and using of an extrema structure in specific tasks. This allows to replace the monotonically convergent (by the criterion) limited search for invisible extrema f(x) → extr(x), x € D; with a full-fledged purposeful movement towards a visible extreme state x → extr(x), x € D; even without satisfaction this monotony and so fundamentally achieve global or similar solutions. In the 1975s this problem was successfully solved in a tasks of radio electronic equipment computer-aided design, which allowed to achieve sub-global solutions for complex optimization criteria and radically improve the quality of real electronic components, but still has not received due attention in optimization theory despite publications in international publications. As a result of numerous experiments, the multi-extremes nature of real complexity and dimensionality problems was revealed, which was caused by the initial, usually hierarchical, heterogeneity of the optimization object of regardless of the optimization criterion. Heterogeneity generates the micro- and macro-orders of the object's optimization state for some given criterion, which respectively means the degree of optimization in strongly connected groups of object components and connected groups among themselves. In this case, the micro-order is a new optimization concept, expanding the concept of local extremum with a greater degree of optimization in the general case. Due to the prevailing optimization in connected groups, the micro-order is ahead of the macro-order and so generates a local extremum. Obviously, a global extremum corresponds to a state with an optimal hierarchical macro- and micro-orders. This state is controlled by the corresponding observable signs, in particular, the distribution curve of the components by the criterion value, which in a quasi-optimal state should approach a relatively smooth exponential / Poisson form. Smoothing this curve in micro-order states (for the initial criterion) at all levels of the object hierarchy becomes the object optimization goal instead of the original optimization criterion. Since heterogeneity is weakly manifested in up to 5-10 components of an object, this method provides a real hierarchical unimodal sub-global optimization of objects of any large dimension. The method is universal for many criteria and classes of objects and due to the extreme origin of universe entities is inherent in many phenomena and the fundamentally heterogeneous Universe as a whole, ensuring their continuous movement and development.

Keywords: Meta-concepts, Extremes, Global optimization, Constructivization, Universal method

The temperature Kurdyumov's sharpening modes in the uranium - plutonium fission fuel of epithermal wave-travelling reactor

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Realization of the nonlinear temperature Kurdyumov's sharpening modes in the uranium - plutonium fission media can affect significally on the kinetics of nuclear reactors, including perspective epithermal wave-travelling reactor of the V generation (a Feoktistov type reactor). For the uranium - plutonium fission media dependences of thermal source density on temperature of the fission media are received at various concentration of plutonium. Preliminary decisions of the transfer heat equation for uranium - plutonium fission media for the technical reactor conditions demonstrated the realizations of the modes with Kurdyumov's sharpening. The submitted results specify an opportunity of local meltings of the uranium - plutonium fission media.

Keywords: Kurdyumov's sharpening modes, Temperature, Uranium - plutonium fission media, Epithermal wave-travelling reactor, Simulation

The relationship between the Hurst exponent, the ratio of the mean square successive difference to the variance (Abbe value), and the number of turning points of a time series

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In search for a simple estimator of the Hurst exponent (H), the dependence of the Abbe value (A) and the number of turning points (T) was investigated. It was found that the T(H) and A(H) correlation are very tight. Moreover, various type of processes (e.g., fractional Brownian and Gaussian ones) are clearly separated in the A-T plane. This finding has been already used in various fields, like physiology or stock market analysis. Its ability to differentiate regular, chaotic and stochastic processes makes it a powerful classifier. Its applicability in constraining the power spectral density is demonstrated on astrophysical light curves.

A Symbolic Approach to Lyapunov Characteristic Exponents

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Benettin's algorithm of 1990 remains the standard tool to estimate Lyapunov Characteristic Exponents of smooth dynamical systems. In this talk, we present a new calculation technique based on the direct calculation of a high order series approximation to the first variation. The form of our general approximate solution decreases computation time, and allows the analysis of system sensitivity to included parameters. Several examples will be presented.
Keywords: LCE, numerical methods, power series, symbolic solution

Self-organization of structure of the poetic literary texts of V. S. Vysotsky

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Self-organization of the literary poetic text is a new uninvestigated domain of system theory. However, the understanding of self-organization processes as well as self-renewal of poetic structure is key for an analysis of system prosody functioning. These processes determine both as occurrence of new poetic texts in the belles-lettres and their interrelation with the already known works of art. The functioning of systems prosody directly depends on the language environment of their use, as well as processes of self-organizationing occurring in a language under investigation. In particular, the process of self-organization of poetic literary texts of Vladimir S. Vysotsky is analyzed in the given research. Here it discussed how we have to consider the process of creating literary works: as a chaotic stream of consciousness or as a deliberate creative process? According to the ancient Greek philosophy, the chaos (χαωσ) means a chaotic mix of material constituent elements of the world from which there was all existing The chaos was represented by the ancient Greeks through primitive elements as an abyss, a complete gloom and a fog. As a result of chaos overcoming an order became in the form of the cosmos (κωσμωσ) meaning order of material all constituent elements (in the nature, in the state and the society). The representation about an initial state condition of the world as absence of any mounting or organization as about in the amorphous and chaotic form was inherent in peculiar not only the ancient of Greek philosophy, but other also almost to all without exception to ancient philosophies (ancient Egyptian, ancient Indian, ancient Chinese etc.). A transition from the chaos to the cosmos space, from the elements of isolated sounds and words to the ordered of the poetic text, from the chaotic of art products to the ordered system of literature, sorts can be also considered as a process of development existence of fiction in the form as kind of art, i.e. as a complex system of art. That is why it is necessary to note that the processes of self-organization play conducting the principal role here.

Keywords: self-organization of literary text, chaos, structure, system

Nonlinear Phenomena in an Interrupted Electric Circuit with State Dependent Input

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The subsystem switches depending on state and time is called hybrid system[1]. Bifurcation phenomena occurring in the power conversion circuit have been energetically studied since the 1990's [2][3]. In this report, we propose a simple interrupted electric circuit which simulates the switching action of the current-mode controlled DC-DC converter with thermo electric module. Using the return map, we discuss the fundamental characteristic of the circuit.
The circuit model and bifurcation diagram of hybrid system with state dependent input are shown in Fig.1 The circuit parameters are follows:

R = 100[Ω], C = 100[uF], E = 5[V], f = 1[Hz], a = 1, b = 2. (1)

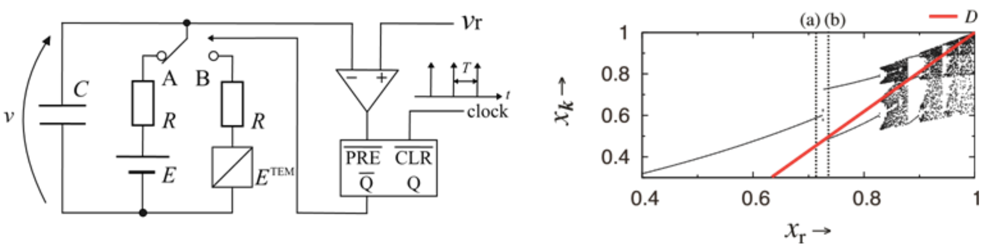
The circuit equation during the switch is A and B are given by

RCdv = { E_{TEM}− v, SW is A dt E − v. SW is B (2)

The output characteristic of the state-dependent input is

$$E^{TEM}(t) = -av + b. \quad (3)$$

Where, a and b are arbitrary values.



(a) Circuit model. (b) Bifurcation diagram.

Figure 1: The circuit model and bifurcation diagram of hybrid system with state dependent input.

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Innovation Methods in Management Risks at Mass Casualty Emergencies

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Today it is observed the intense growth of various global wide scale threats to civilization, such as natural and manmade catastrophes, ecological imbalance, global climate change, numerous hazards pollutions of large territories and directed terrorist attacks, resulted to huge damages and mass casualty emergencies. The humankind has faced the majority of treats at the first time. Therefore, there are no analogues and means to be used for their solving. It stimulates modernization of traditional methods and development of new ones for its researching, prediction and prevention with maximum possible decreasing of their negative consequences. The global issue of safety provision for the humankind is the most actual and requires an immediate decision. Catastrophe risks have increased so much, that it becomes evident, that none of the states is able to manage them independently. Join efforts of all world community are necessary for the substantial development of our civilization. Main obstacles for this realization are under discussion. The authors of this article have their own experience and methods in this direction. Wide scale global catastrophes have not any boundaries. Any political and economical frictions between some states are not the reasons for the implementation of the struggle against them. The total emergency recommendations and actions have to be improved to eliminate and software of negative disaster’s responses on population and environment. This article describes some our examples of realization with using of own Integrated Emergency Management and using of special methods and techniques in the most critical situations, which have taken place in different countries in 21 century.

Excitation of Peregrine-type waveforms from vanishing initial conditions in the presence of periodic forcing

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We show by direct numerical simulations that spatiotemporally localized wave forms, strongly reminiscent of the Peregrine rogue wave, can be excited by vanishing initial conditions for the periodically driven nonlinear Schrödinger equation. The emergence of the Peregrine-type waveforms can be potentially justified, in terms of the existence and modulational instability of spatially homogeneous solutions of the model, and the continuous dependence of the localized initial data for small time intervals. We also comment on the persistence of the above dynamics, under the presence of small damping effects, and justify, that this behavior should be considered as far from approximations of the corresponding integrable limit. Extensions to higher order models are also touched upon.
Keywords: Forced Nonlinear Schrödinger Equation, Time-periodic driver, vanishing initial conditions, modulational instability, Rogue Waves, Peregrine Soliton
Acknowledgments: This research is co-financed by Greece and the European Union (European Social Fund – ESF) through the Operational Programme (Human Resources Development, Education and Lifelong Learning 2014–2020) in the context of the project “Localized and quasiperiodic solutions for partial differential equations: Dynamical paths from mathematical ecology to nonlinear physics” (MIS 5004244).

Mechanical low to high frequency converter via difference combination resonance

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MEMS devices rely on scavenging energy from background fluctuations or vibrations in their environment. Often the fundamental resonance of the mechanical component is in the MHz range, but most vibration energy is present at significantly lower frequencies. We propose a mechanism by which low-frequency vibration energy can be harvested mechanically via parametric resonance of a device that has much higher natural frequencies. At first this seems paradoxical, because it would be like making a drum sound by sending it up and down in an elevator. The principle we exploit is that of difference combination resonance where a resonant response is obtained by excitation at the difference between two fundamental frequencies. While such phenomenon has been proposed in theory, no experimental implementation has previously been found. We propose a simple mechanical manifestation, which takes the form of a double ! pendulum with a pulsatile follower load. It is shown how such a device can be tuned in theory to produce significant energy from input frequencies that are an order of magnitude smaller than either of its two natural frequencies.
Keywords: combination resonace, MEMS, fluid-structure interaction, mechanical low to high frequency converter, follower force

Chaos Generator with Nonlinear Element Based on Metamaterial

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The development of chaotic generators is a difficult task and very important for further design of telecommunication systems. The main part of any chaotic generator is a nonlinear element which is a reason of chaotic behavior of system. Modern radio component base gives a possibility to realize the generators the signals of which occupy the band

of a few gigahertzes. It is due to the characteristics of scheme component are limited by own properties. However, there is a demand on the expansion of the frequency range. Therefore, in this work the metamaterials ware suggested for the realization of the nonlinear element. Metamaterials are perspective artificial materials that possesses by unusual electromagnetic properties such as negative values of permittivity and permeability. It can be easy manufactured using, for example, chemical etching. The modern approaches to rich the metamaterial components of ! nm sizes. With this suggestion one can assume that the possible chaotic generator can oscillate at terahertz frequencies and more.

Keywords: Chaos generator, Nonlinear Element, Metamaterial
Chaotic Oscillations and Circuits

Study on the precipitation stress model of gamma-prime phase of GH4742 alloy during aging process

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GH4742 alloy is a high gamma prime phase contented nickel-base superalloy, which has obvious advantage in high-temperature strength. It is said suitable to use for in key hot components such as turbine disk of aero-engine. However, due to its high gamma prime phase content (nearly 35vol.%), the ingot cracking easy occurs caused by the precipitation of gamma prime phase during alloy solidification after melting or aging process. Therefore, how to control the internal stress of ingot caused by gamma prime phase precipitation is very important. In the present study, the precipitation variation of gamma prime phase(the amount, the size and the shape) in the alloy was quantitative measured during aging process, at the same time, the changing of mismatch degree between the matrix and gamma prime phase was examined through the analyzing of matrix lattice constant during aging process. Based on the contracted in the second phase precipitation strain model, a gamma prime phase precipitation stress model is established. It is found that when aging at 950 ℃, with the increasing of aging time, both the volume fraction and size of gamma prime phase increase, the mismatch degree between the matrix and gamma prime phase increase. This means the increasing of internal

stress in the alloy, while the shape of gamma prime phase keeps in spherical. When aging at 1050 ℃, the same tendency can be found as that aging at 950 ℃, however, the shape of gamma prime phase will change from spherical to cubic. It indicates that the precipitation stress caused by the precipitation of gamma prime phase increases with the increasing of aging time, and the anisotropy internal stress occurs at 1050 ℃. As the result, the local internal stress will be increase larger, which will aggravate the hot cracking tendency of alloy ingot.

Keywords: Precipitation stress model, Nickel base superalloy, Gamma prime phase, Hot cracking, Aging process

Solving the Inverse Frobenius-Perron Problem via Monotonization of Random Variable Transformations

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The inverse Frobenius-Perron (IFP) problem of constructing an ergodic dynamical system model with a prescribed invariant state density is encountered in fields as diverse as physics, biology, economics and engineering. The solution to this problem is, in general, not unique. There is considerable interest from a modelling perspective in a technique that produces multiple distinct solutions to the problem, as these solutions lead to alternative hypotheses of the underlying mechanism which gives rise to the observed statistics in a physical system. Whereas existing techniques provide some freedom in specifying the shape of the map that corresponds to the evolution rule of the system, they produce exact solutions from the class of complete maps, such that each map branch stretches over the entire map interval. This structure restricts the family of power spectra that may be successfully modelled using th! ese maps. We propose a novel technique for solving the IFP problem which produces solutions from the more general class of semi-Markov maps, thereby accommodating power spectra with multiple modes. A constructive proof is presented regarding the existence of monotonic random variable transformations for evolving from one prescribed probability density to another. The invertibility of these transformations is subsequently exploited to solve the IFP problem in an exact fashion. The technique is demonstrated by constructing multiple semi-Markov transformations with invariant densities consisting of first and second order polynomials, and with distinct multi-mode power spectra. It is concluded that the proposed

technique provides greater freedom than existing techniques in modelling complex phenomena that produce densities of states.

Keywords: Ergodic map, Inverse Frobenius Perron, Invariant density, Markov map, Power spectrum

Stability of the Iteration Process to Estimate Weibull Parameters According to Small Number of Right-Censored Life Data

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Life distribution and survival probability estimation often have to be accomplished based on very limited information. In such a situation, Monte Carlo sampling technique can be applied to generate virtual life data for any life probability distribution. Inversely, the probability distribution parameter can be estimated according to the virtual life data. Therefore, the virtual life date coming from a Weibull distribution can be applied to characterize the relationship between the estimated Weibull location parameter and the minimal observation in a sample of size n. With such obtained (minimal observation - location parameter) – sample size equation, the estimated Weibull location parameter is a function of the minimal observation or the censoring time (in the condition of single censoring, the censoring time is conservatively taken as the minimal observation) and the number of the censoring data, as well as the Weibull scale parameter (Weibull shape parameter is normally assigned by failure mechanism and empirical knowledge of the estimation item). Meanwhile, the scale parameter estimator is a function of the location parameter. It means that the location parameter cannot be estimated according to a small size sample of right-censored life data unless the scale parameter is available, or only when the location parameter is known, the scale parameter can be estimated. To begin with, an initial location parameter such as $\gamma_1=0$ must be provided. With this γ_1, a scale parameter η_1 can be estimated. Obviously, this is the situation for two-parameter Weibull distribution estimation. Since most of the mechanical and electrical product life follows three-parameter Weibull distribution, such obtained location parameter γ_1 and scale parameter η_1 cannot perfectly characterize the true life distribution. To get better estimation for the Weibull location parameter and scale parameter, a new location parameter γ_2 can be estimated based on the known scale parameter η_1.

Then, a different location parameter γ_2 (γ_2>0) is obtained, that is qualitatively better then γ_1 to characterize the product life distribution. Further, the firstly estimated scale parameter can be updated as η_2 based on γ_2. Such a iterative procedure can proceed infinitely and the estimated location parameter and scale parameter will be updated continuously. It is found that the slightly different location parameter – sample size relationships will lead to much different iterative process and much different parameters estimated for the Weibull distribution. The present paper presents the Weibull distribution parameter estimation process, discusses the stability of the iteration process and the selection of the location parameter – sample size equation, and highlights the complex behavior of the location parameter – scale parameter non-linear interaction..
Keywords: Life distribution, Survival probability, Virtual life data, Monte Carlo sampling, Non-linear interaction

Exponential synchronization of chaotic systems with parameter mismatches

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In this article the exponential synchronization between chaotic systems with mismatch parameters is investigated. The effect of mismatch parameters on exponential synchronization of chaotic systems is also studied. The exponential synchronization is achieved using exponential stability theorem and some lemmas. The error functions exponentially converge to zero when time becomes large. Numerical simulations and graphical results are presented and verify the theoretical results.
Keywords: Synchronization, Chaotic systems, Exponential stability theorem, Parameters mismatch

The Fluid Dynamics of Spin - a Fisher Information Perspective

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Two state systems have wide applicability in quantum modelling of various systems. Here I return to the original two state system, that is Pauli's electron with a spin. And show how this system can be interpreted as a vortical fluid. The similarities and difference between spin flows and classical ideal flows are elucidated. It will be shown how the internal energy of the spin fluid can partially be interpreted in terms of Fisher Information.

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Innovation Processes and Chaos in Economic Systems

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The prospects of development of world economy is now usually associated with formation of innovative economy. The innovation as a peculiar form of chaos can become a push and the mechanism of an exit to one of possible trajectories of development corresponding to internal tendencies of economic system and providing its new qualitative state. In it is the constructive role of innovative factors for start of processes of self-organization in system and preparation it to various scenarios of development consists. The innovation as kind of chaos is the factor bringing nonlinear systems to own structures attractors. As innovations are a chaos element in relation to the existing economic system, their introduction causes the self-organization process directed on adaptation of a new element in structure in system. For adaptation acceleration, the system develops internal reciprocal innovations, interrelations between elements become complicated, and the structure of system changes. At the first stage of self-organization for ensuring stability of system the number of its reactions has to correspond to quantity of external signals. The system builds structure in which to each external influence, there corresponds the element capable to generate internal innovations and to influence change of structure of system. At the following stage the economic system evolves in the direction of more and more ordered state. It is reached by means of hierarchy of elements: order parameters are established, the principle of submission joins, the effective group of the uniform internal innovations allowing to adapt with the smallest changes in structure of system, and, therefore, with the smallest expenses is provided. The system is in relative balance, and crucial importance is gained by the endogenous innovations promoting the fastest adaptation and self-organization. The economic system selectively approaches response to exogenous innovations, setting the rigid mode for their penetration. She perceives only the influences answering to its nature, any other can negatively work, up to implementation of scenarios of chaos. Having reached a certain degree of internal force, nonlinear systems become more active, structure external space according to the dynamic nature. Thus, property of innovation can be considered as violation of a habitual order of functioning of system. Contradictions, the conflicts and bankruptcies which accompany development of economic system can be connected with it. Similar processes can be softened, predicting the coming social and economic transformations or, on the contrary, to aggravate, consciously provoking the operated conflicts and chaotic processes. For the purpose of modeling of such scenarios the model of transition to innovative products is constructed and the analysis of chaotic processes which arise during introduction of innovations is made.

Keywords: Innovative economy, Innovations, Chaotic modeling, Model of innovative strategies, Chaotic simulation

Synchronization and Its Analysis in Thermoacoustic Instability Induced in Combustion

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Combustion instabilities are complicated phenomena, involving much more singular or nonlinear behaviors, in gas turbines and ramjet engines. In particular, they become obstacle in the development of aircraft with higher performance. Among combustion instabilities, thermoacoustic instability is encountered frequently and characterized by rapid fluctuations of heat release, pressure, and large-amplitude oscillations of one or more natural acoustic modes of the combustor. It has been found that acoustic oscillations are excited by thermal sources, so the resulting phenomena are often referred to as thermoacoustic instabilities. Following Navier-Stokes equations and nonlinear dynamics, a mathematical model involving vortex shedding is presented to study thermoacoustic instability. Then, the nonlinear dynamics, such as frequency hopping, synchronization, phase-locked, and Devil's staircases, are captured numerically with Galerkin procedure, and the influences of system parameters on the nonlinear dynamics listed above are further analyzed. More, some typical routes to thermoacoustic instability and chimera state in an interval are presented. Finally, the natures or mechanism of nonlinear behaviors are explained, in comparison with existing experiments, and hence some control methods are proposed and verified numerically.

As a conlusion, the results presented could give explanation of thermoacoustic instability occurred in combustion, and could be used to develop some available control methods.

Keywords: Thermoacoutics, Combustion, Instability, Synchronization, Phase-locked, Chaotic behavior, Bifurcation

Finite-time chaos synchronization of the delay hyperchaotic Lü system with disturbance

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In this paper, the dynamics and the finite-time synchronization of the delay hyperchaotic Lü system with disturbance are discussed. Based on the finite-time stability theory, a control law is put forward to realize finite-time chaos synchronization of the delay hyperchaotic Lü system with disturbance. Finally, numerical simulation results are provided to demonstrate the effectiveness and robustness of the proposed scheme.
Key words: Chaos; delay system; disturbance; finite-time synchronization

The George Tsironis Symposium

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rf SQUID Metamaterials: A Nonlinear Life

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Through experiments, numerical simulations, and theory we explore the behavior of strongly nonlinear 0D, 1D, and 2D rf SQUID (radiofrequency superconducting quantum interference device) metamaterials, which show extreme tunability and nonlinearity [1-3]. We investigate the SQUID metamaterial as a nonlinear medium through detailed two-tone intermodulation (IM) measurement over a broad range of tone frequencies and tone powers [4]. A sharp onset followed by a surprising strongly suppressed IM region near the resonance is observed. Using a two time-scale analysis technique, we present an analytical theory that successfully explains our experimental observations. The theory predicts that the IM can be manipulated with tone power, center frequency, frequency difference between the two tones, and temperature. The spatial response of the rf SQUID lattice under cryogenic conditions and rf and dc flux bias is investigated with a laser scanning microscope (LSM). LSM photoresponse images at zero dc flux and low rf flux bias show no evidence of large-scale coherent response from the rf SQUID lattice. Instead we find small clusters of coherent SQUIDs adopting a variety of resonant frequencies. Spatial synchronization of the rf SQUIDs occurs under increased rf flux bias,[5] in agreement with our earlier results based on global transmission measurements and simulation [3]. Motivated by the predictions of our colleague G. P. Tsironis, we expect that many other interesting collective behaviors will be discovered in this remarkable nonlinear metamaterial.
Keywords: Nonlinear metamaterial, SQUIDs, Superconductivity, Chaos, Chimera.
Acknowledgements: This work was done in collaboration with A. P. Zhuravel, M. Trepanier, D. Zhang, S. Bae, J. Cai, E. Ott, T. M. Antonsen, and A. V. Ustinov, and UMD research is supported by the U.S. Department

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Pterobreathers in their moving frame

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Discrete moving breathers are moving localized vibrations in a nonlinear lattice that are transient solution of the Hamiltonian, although often with long flight paths. Pterobreathers are similar entities but coupled to a nonlinear plane wave, called wing. Pterobreathers can be constructed as exact solutions with a given symmetry and often they have small wings. We propose a description of pterobreathers in their moving frame based in the concept of fundamental time and frequency. The complexity of the breather spectrum is thus reduced to just two frequencies, the internal breather frequency and the wing frequency. Exact solutions allow for the use of continuation methods in terms of the frequency and thus allow for the obtention or pterobreathers with no wings, or exact moving breathers, for a specific frequency in each symmetry. We apply the theory to a realistic model for a layered silicate.

Keywords: moving breathers, pterobreathers, moving frame, nonlinear lattices, exact moving breathers, nonlocality

New PT-symmetric systems with solitons: nonlinear Dirac and Landau-Lifshitz equations

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Although the spinor field in (1+1) dimensions has the right structure to model a dispersive bimodal system with gain and loss, the plain addition of gain to one component of the field and loss to the other one results in an unstable dispersion relation. In this talk, we advocate a different recipe for the PT-symmetric extension of spinor models -- the recipe that does not produce instability of the Dirac equation. We consider the PT-symmetric extensions of nonlinear spinor models and demonstrate a remarkable sturdiness of spinor solitons in two dimensions. Another new class of PT-symmetric systems comprises the nanoferromagnetic films with spin torque transfer. In the vicinity of the exceptional point, the corresponding Landau-Lifshitz equation reduces to a nonlinear Schroedinger equation with a quadratic nonlinearity. In the simplest, isotropic, case the equation has the form iψt + ψxx – ψ + ψ2=0. We show that this PT-symmetric Schroedinger equation has stable soliton solutions.
Keywords: Parity-time symmetry, gain and loss, nonlinear Dirac equations, Landau-Lifshitz equation, spin torque transfer, dissipative solitons

The Effect of Long Range Interactions on the Dynamics and Statistics of 1D Hamiltonian Lattices

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I will first review recent results with H. Christodoulidi and C. Tsallis on how the dynamics and statistics of β – FPU 1D Hamiltonian lattices are affected by long range interactions (LRI) in their potential (1/rα, 0 ≤ α < ∞) leading to the onset of a weak form of chaos dynamically as well as statistically in the thermodynamic limit [1,2]. Similar effects also occur in 1D Hamiltonians with LRI in the presence of on site potentials of the Klein Gordon (KG) type [3]. I will then report on more recent findings with J. Macias Diaz and H. Christodoulidi, which show that LRI influences significantly the important effect of nonlinear supratransmission in Hamiltonian 1D lattices: Specifically, we find for the FPU case that threshold amplitudes increase the longer the interaction (α → 0) [4] while for Hamiltonians with KG on – site potentials, there is a sharp decrease of the threshold amplitudes, 0 ≤ α < 1.5 [5], which still remains a mystery!

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The Subtle Road to Equilibrium in the FPUT Model

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The interpretation and consequences of the celebrated Fermi, Pasta, Ulam, Tsingou (FPUT) numerical experiment have challenged scientists for more than six decades.

The history of how the original FPUT discovery led to the theory of "solitons," was key in the understanding of Hamiltonian chaos, and led to the birth of "nonlinear science" is well documented, but there are many fascinating details which are only now being explored and understood. In this presentation, I will discuss two recent examples: namely, the existence and breakdown of recurrences and super-recurrences in both the alpha- and beta- versions of the FPUT system, and the remarkable intermittent dynamics, involving long-time, large deviations, that occur once the systems has nominally reached equilibrium.

In the first study1, we find higher-order recurrences (HoR)s—which amount to "super-super-recurrences" in both the alpha and beta models. The periods of these HoR scale non-trivially with energy due to apparent singularities caused by nonlinear resonances, which differ in the two

models. Further, the mechanisms by which the HoR breakdown differ strikingly in the two models.
In the second study2, we find that the dynamics at equilibrium is characterized by a power-law distribution of excursion times far off equilibrium, with diverging variance. Long excursions arise from sticky dynamics close to localized excitations in normal mode space (q-breathers). Measuring the exponent allows to predict the transition into nonergodic dynamics.
*Work in collaboration with Carlo Danielli, Sergej Flach, and Salvatore Pace,

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Discrete breathers affect macroscopic properties of nonlinear lattices

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Defect-free crystal lattices can support spatially localized, large amplitude vibrational modes called either discrete breathers (DBs) or intrinsic localized modes (ILMs). This has been confirmed by a number of molecular dynamics and in a few cases first-principle simulations. There exist many experimental measurements of crystal vibrational spectra aiming to prove the existence of DBs in thermal equilibrium at elevated temperatures. However these experimental results can be interpreted in different ways and they are still debated. Direct high-resolution imaging of DBs in crystals is hardly possible due to their nanometer size and picosecond lifetime. An alternative way to prove the existence of DBs in crystalline solids is to evaluate their impact on the measurable macroscopic properties of crystals. In fact, such measurements of heat capacity have been done for alpha-uranium by Manley with co-workers. In the present study, with the use of a simple 1D and 2D nonlinear lattices, we analyse the effect of DBs on heat capacity, thermal expansion, elastic constants, and thermal conductivity. In the most transparent way this can be done by monitoring the lattice parameters in a non-equilibrium process, during the development of modulational instability of the zone-boundary

mode (q=□) or the gamma-mode (q=0), with total energy of the chain being conserved. It is well-known that the instability results in the appearance of long-lived DBs that gradually radiate energy and eventually the system approaches thermal equilibrium with spatially uniform and temporally constant temperature. The variation of heat capacity and other macroscopic properties at constant volume is evaluated during this system transformation. It is concluded that DBs affect all the above mentioned macroscopic characteristics of the studied nonlinear lattices.
Keywords: discrete breather, intrinsic localized mode, nonlinear lattices, heat capacity, thermal expansion, elastic constants, thermal conductivity

Energy Localization in Hydrogenated Metals: Applications to the Rate Theory

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Energy localization in crystals manifest itself as intrinsic localized modes or discrete breathers (DBs). We present atomistic simulations of DBs in nickel, palladium and their hydrides. Large amplitude atomic motion in DBs may result in time-periodic driving of adjacent potential wells occupied by hydrogen ions (protons or deuterons). This driving has been shown to result in the increase of amplitude and energy of zero-point vibrations and in broadening of the wave packet. In this context, we present numerical solution of Schrodinger equation for a particle in a non-stationary double well potential, which is driven time-periodically imitating the action of a DB. We show that the rate of tunneling of the particle through the potential barrier separating the wells is drastically enhanced by the driving with a resonant frequency ranging from w0 to 2w0, where w0 is the eigenfrequency of the potential well. The effect increases strongly with increasing amplitude of the driving. These results support the concept of DB mediated catalysis and extend it to low temperatures where quantum tunneling prevails over thermal activation controlling the reaction rates in solids.
Keywords: Discrete breathers, Quantum Tunneling, Rate Theory, Catalysis.

Chiral Optical Systems Obeying Space Inversion and Time Reversal Symmetry

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Although chirality seems to be in general incompatible with space and time symmetry, we show that special optical systems exist combining chiral loss and chiral gain components and obeying space inversion and time reversal symmetry, in the sense that the permittivity, the permeability, and the chirality transform under the action of PT as follows: These systems possess an Exceptional Point below which the eigenvalues of the transfer matrix are real in spite of the non-hermitian nature of the Hamiltonian and even when the chirality violates the requirement of PT symmetry. This freedom regarding the chirality can be explored by considering realistic chiral metamaterials, finding by retrieval their permittivity, permeability, and chirality, and simulating their behavior towards desired optical properties such as optical rotation, ellipticity, anisotropic transmission, etc. Possibilities for exciting applications open up.

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to appear in Phys. Rev. Lett.

Perfect Control of Optical Beams

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There are three fundamental features that characterize an optical beam: its beam-width, its amplitude, and the trajectory the it follows. We examine the possibility to generate optical beams where we can simultaneously control these properties. We focus in the case of two different classes of optical waves: Bessel beams and Airy/accelerating beams. Although the underlying mechanism for the generation of such classes of optical waves is fundamentally different, it is still possible in both cases to engineer their properties in generating a beam with pre-defined characteristics.

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Pattern Formation and Chimeras in Squid Metamaterials

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The radio frequency (rf) Superconducting QUantum Interference Device (SQUID) is a highly nonlinear oscillator exhibiting rich dynamical behavior. In the present work, the dynamical properties of the SQUID in the strongly nonlinear regime are demonstrated using a well-established model whose parameters lie in the experimentally accessible range of values.
When driven by a time-periodic (ac) flux either with or without a constant (dc) bias, the SQUID exhibits extreme multistability at frequencies around the (geometric) resonance. This effect is manifested by a ``snake-like'' form of the resonance curve. In the presence of both ac and dc flux, multiple bifurcation sequences and secondary resonance branches appear at frequencies above and below the geometric resonance.
When arranged in repeating motifs, SQUIDs form metamaterials, i. e. artificially structured media of weakly coupled discrete elements that exhibit extraordinary properties e. g. negative diamagnetic permeability. We report on the emergent collective dynamics of one- and two-dimensional lattices of coupled SQUID oscillators, which involve a rich menagerie of spatio-temporal dynamics including chimera states, and their potential control through the flux bias.

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Quench Dynamics and Thermalization in Isolated Systems of Interaction Particles

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The onset of quantum chaos and thermalization is studied in isolated systems of interacting bosons and fermions. The goal is to establish the conditions under which the properties of energy spectra and eigenstates can be described with the use of Two-Body Random Interaction models. It was shown that under these conditions the spread of wave packets in the Hilbert space follows an exponential time dependence, thus leading to a linear increase of Shannon entropy. After the saturation, this entropy can be treated as the thermodynamical one and its value is defined by the spread of local density of many-body eigenstates in the energy shell created by the projection of the total Hamiltonian onto the unperturbed one. We demonstrate that the results can be also applied to integrable systems with no random parameters, such as to the celebrated Lieb-Liniger model describing the point-like interaction between bosons in 1D optical traps.

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Uniaxial compression and buckling of graphenes

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The mechanical response of single- and multi-layer graphenes [1], as well as of graphene nanoribbons of various lengths and widths [2], under uniaxial compression is presented. Molecular dynamics simulations are used to calculate compressive stress-strain curves and critical buckling values. The dependence of the critical buckling on the size of graphenes is discussed. In graphene nanoribbons, a single master curve describes the variation of the critical buckling with the aspect ratio of the nanostructure. The obtained results are compared with the predictions of the continuum elasticity theory [3-5].

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Abrupt Transitions from the Interplay of Nonlinearity and Diffusion: Applications to Population Extinction in Bacteria and Epidemics

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The interplay of nonlinearity and diffusion is shown to lead to fascinating consequences such as abrupt extinction of populations in bio/ecological systems. The applications demonstrated are for the quite different systems of bacteria in a Petri dish and the spread of the Hantavirus epidemic arising from random walks of rodents on the New Mexico terrain. The former analysis is exact while the latter develops controlled approximation procedures. The basic dynamic equations are modified Fisher equations. Early references below exemplify the subject.

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Symmetry Breaking in Topological Nonhermitian Photonics as an Enabler of High-Performing Devices

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The interplay between non-Hermiticity and topology, due to inhomogeneous gain and loss distributions, along with the nonlinearity of a photonic system, is shown to result to fascinating dynamical features. The latter are very promising for advanced functionality of next-generation integrated photonic devices and structures, especially in the case of non-trivial asymmetric gain and loss inhomogeneities. Such configurations allow for controlled formation and propagation of solitary beams in planar inhomogeneous photonic structures [1], tailored modulation response crossing the 100GHz barrier [2], controlled location of exceptional points for enhanced sensitivity [3] and localized synchronization [4] in coupled lasers, as well as targeted transfer of energy in active couplers [5].

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Nonlinear spatially localized vibrational modes in metals

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Crystal lattice dynamics is one of the most important branches of condensed matter physics. When studying nonlinear oscillations in crystal lattices, their spatial dimension is of great importance. There exist one-dimensional crystals (polymer chains, carbin, DNA, etc.) as well as two-dimensional crystals (graphene, silicene, boron nitride, etc.), but the vast majority of crystals used in practice are three-dimensional. In one-dimensional crystals, discrete breathers (DBs) or intrinsic localized modes (ILMs) are exponentially localized in space, zero-dimensional objects. In two-dimensional crystals, both zero-dimensional and one-dimensional DBs are possible, in the latter case they are spatially localized along one coordinate direction and delocalized along the other. This means that a one-dimensional DB is localized on a chain of atoms and the vibration amplitudes decrease exponentially with distance from the chain. By analogy, in three-dimensional crystals one can speak of zero-dimensional, one-dimensional, and two-dimensional discrete breathers. In the latter case, it is assumed that atoms are excited along a certain atomic plane, and, with distance from this plane, the amplitude of atomic oscillations decrease exponentially. It should be noted that the possibility of the existence and properties of one-dimensional and two-dimensional DBs in three-dimensional crystals has hitherto been unknown and work has not been done in this direction.
In this study properties of zero-dimensional, one-dimensional and three-dimensional DBs in fcc Al, Cu and Ni, as well as in hcp Ti are analysed with the help of molecular dynamics simulations based on many-body potentials. Delocalized nonlinear vibrational modes (or bushed of normal nonlinear modes) derived by Chechin with co-workers are widely used for excitation of two-dimensional DBs.
Overall, DBs of new type are analysed in pure metals. It is demonstrated that the same metal can support various spatially localized nonlinear vibrational modes.
Keywords: discrete breather, intrinsic localized mode, metal, fcc lattice, hcp lattice

Nonlinear dynamics in SQUID arrays

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Metamaterials, i.e., artificial media designed to achieve properties not available in natural materials, have been the focus of intense research for more than two decades. Many properties have been discovered and multiple designs have been devised that lead to numerous conceptual and practical applications. SQUID (superconducting quantum interference device) arrays in various geometries operate as magnetic metamatrials, producing further specificity and functionality. Such SQUID metamaterials [1-3] are both theoretically and experimentally investigated and exciting new phenomena have been found. The SQUID is a unique nonlinear oscillator that encompass the Josephson effect and can be manipulated through multiple external fields. This domain flexibility is inherited to SQUID metamaterials, which present a nonlinear dynamics lab where numerous complex spatiotemporal phenomena may be explored. An overview of nonlinear dynamics in SQUID arrays, with the emphasis on basic propert! ies related to their individual and collective responses to external magnetic fluxes, is given. Specifically, properties such as multistability and chaos in single SQUIDs, as well as resonance tunability and the emergence of various spatially inhomogeneous states (such as intrinsically localized [4], chimera [5], and patterned states) in SQUID metamaterials, are discussed. Moreover, SQUID metamaterials with specific lattice geometries (e.g., on a Lieb lattice), reveal the possibility of flat-band localization [6] as well as the emergence of peculiar spatially-synchronized temporally-chaotic states [7].

Keywords: Superconducting metamaterials, SQUIDs, chimera states, intrinsic loclization, flat-band localization

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Stellarator Mathematics: Hidden Symmetries of Guiding Centre Motion

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The study of confinement of a charged particle in a strong magnetic field has been greatly aided by an excellent approximate symmetry, namely rotation of the particle's "gyroradius vector" around its "guiding centre". This reduces the problem (to high accuracy) to that of confining the guiding centre. If the guiding-centre motion has a continuous symmetry then the guiding centre is confined to a specific region associated to its initial condition, generically the projection of an invariant 2-torus to position-space. More formally, the guiding-centre motion is "integrable".
An obvious example of such symmetry occurs if the magnetic field has rotation symmetry about some axis. This is the principle of tokamaks. They have the defects, however, that they need a strong toroidal current to make the confinement tight, driving such a current for long times is not easy, and it generates instabilities.
Stellarators are a class of magnetic confinement devices in which no toroidal current is required. To achieve integrability without axisymmetry, however, requires a hidden symmetry, called quasi-symmetry. Although this can be achieved to a good approximation, it is widely believed that exact quasi-symmetry is impossible. Yet it is worth keeping in mind the amazing result of Kovalevskaya that in addition to the axisymmetric integrable tops of Lagrange there is a family of non-axisymmetric integrable tops. I will report on strong constraints that we have derived on quasi-symmetries.

Coherent wave propagation in multi-mode systems with correlated noise

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Imperfections in multimode systems lead to mode-mixing and interferences between propagating modes. Such disorder is typically characterized by a finite correlation time (in quantum evolution) or correlation length (in paraxial evolution). We show that the long-scale dynamics of an initial excitation that spread in mode space can be tailored by the coherent dynamics on short-scale. In particular, we unveil a universal crossover from exponential to power-law ballistic-like decay of the initial mode. Our results have applications to various wave physics

frameworks, ranging from multimode fiber optics to quantum dots and quantum biology.

Non-Hermitian Wave control in Complex Photonic Media

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In this talk we are going to present recent results concerning wavefront control in disordered, nonlinear, and non-hermitian complex photonic media.
Symposium honoring the 60th birthday of Professor Giorgos P. Tsironis

Peak-end Memory: An extension to Asymmetric Choices

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The peak-end rule [1] of behavioural economics is a psychological heuristic which describes the way us humans tend to particularly remember extreme and recent experiences. Recent work modelling this effect in a simple discrete-choice model (a random walker with extreme-value memory) revealed how this memory distortion could qualitatively affect the long-time behaviour [2]. We report preliminary investigations, extending the framework to the asymmetric case where the two possible choices have different distributions of experience. This opens up the possibility that, due to the peak-end memory, the agent becomes trapped in the rationally-less-good choice. The probability of this trapping depends on the level of noise in the decision-making process. Significantly, we present numerical evidence that there is an optimal value of noise maximizing the agent's expected experience and we discuss analytical approaches to predict this.

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Designing quantum many body Hamiltonian from quantum circuits of superconducting qu-bit line

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Quantum superconducting circuits have become recently a new alternative description of quantum phenomena such as entanglement or quantum computation in low temperature microship devices.
We report on the ability of a transmon (qu-bit) 1D array device embedded in a wave guide to act as an emitter of entangled pair of microwave radiation. The self and mutual capacitance of a series of such aligned transmon is used to allow the propagation a plasmon-like collective excitation with a tailored dispersion relation. These excitations are produced by a sudden sweep of the carrier number inside these devices. By a suitable design of a quadratic coupling from the Josephson junctions, they can decay collectively into a pair of entangled photons beam whose the maximum intensity is only bounded by the number of emitters. As a result, the quadratures obtained from a homodyne detection of these outputs beams form a pair of correlated continuous variables similarly to the EPR experiment. We calculate the decay rate of the transmon excitation both into a continuum of photon state and into a one-mode cavity. In the latest, we determine the Rabi-like frequency oscillation with the transmon mode resulting from a detuning.
References: Transmon excitation as a resource for entanglement of continuous variables in the microwave regime, P. Navez, A. Sowa and A. Zagoskin (preprint soon)

Chimera States in Brain Dynamics

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Chimera states are mixed states composed of coexisting coherent and incoherent domains in networks of coupled nonlinear oscillators. Chimeras are particularly relevant in brain dynamics where neuronal oscillators organized in complex networks exchange electrical and chemical signals. Using as working example the Leaky Integrate-and-Fire (LIF) model to represent the single neuron dynamics, we study the collective hehaviour of coupled LIF elements. We discuss the parameter values which give rise to chimera states and the influence of the network connectivity in the frequency profile of the coherent and incoherent domains. Some insights regarding the mechanisms giving rise to chimera states are presented.

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On multi-dimensional compact solitary patterns

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As though to compensate for the rarity of multidimensional integrable systems in higher dimensions, spatial extensions of many of the well-known nonlinear dispersive equations on the line, exhibit a remarkably rich variety of solitary patterns unavailable in 1-D. Our work systematizes this observation with a special attention paid to compactons - solitary waves with compact support - where this effect is found to be far more pronounced and begets a zoo of multi-dimensional compact solitary patterns.
One manifestation of this phenomenon is found in the sublinear NLS and Complex Klein-Gordon where the compactons inducing mechanism coupled with azimuthal spinning may expel the compact vortices from the origin to form a finite or countable number of genuine ring-vortices. Such rings are an exclusive feature of compacton supporting systems.

Power-law Kink Tails in Higher Order Field Theories

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Since the initial observation of a power-law tail in a phi-8 field theory [1], we have recently found several examples of a large class of one-dimensional higher order field theories with kink solutions which asymptotically have a power-law tail either at one end or at both ends [2,3]. We provide analytic solutions for the kinks in a few cases but mostly provide implicit solutions. We also provide examples of a family of potentials with two kinks, both of which have power law tails either at both ends or at one end. In addition, we show that for kinks with a power law tail at one end or both the ends, there is no gap between the zero mode and the continuum of the corresponding stability equation [4]. This is in contrast to the kinks with exponential tail at both the ends in which case there is always a gap between the zero mode and the continuum. Moreover, we obtain analytically and verify numerically the kink-kink and kink-antikink interaction for representative higher-order field theories [5]. Finally, we provide some examples of logarithmic potentials with power-law kink tails.

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Topological Photonics

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The fundamental concepts underlying the new area of Topological Photonics will be presented, along with exciting applications such as topological insulator lasers, new ideas related to photonic topological insulators in synthetic dimensions, topological protection of entangled states, exciton-polariton topological insulator, current challenges and open questions.

Controlling localized patterns in coupled array of semiconductor lasers

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Phased arrays of optically coupled semiconductor lasers are systems possessing radically complex dynamics that are useful for numerous applications in beam forming and beam shaping.
Previously, stable asymmetric phase-locked states in an active photonic dimer have been theoretically investigated showing new dynamical behavior [1-2]. The asymmetry comes from carrier densities corresponding to values that are above and below threshold resulting in gain and loss coefficients of opposite signs in each laser, so that the respective electric fields experience gain and loss [3]. We investigate for the first time a coupled array of active photonic dimers consisting of two qw lasers in driven externally with differential pumping rates.
We find that localized oscillations close to the fix point coexists with large amplitude oscillations where their field amplitudes and phases can be dynamically controlled by appropriate gain values in each dimer. Different spatial patterns such as chimera [4] and breather like states [5] are fully controllable even for random detuning, showing the path top on demand generation of optical diverse waveforms.

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Nonlinear and Switchable Superconducting Metamaterials

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Superconducting circuits with Josephson junctions allow for utilizing compact low-loss resonators with well-controlled nonlinearity and frequency tunability in the microwave and mm-wave frequency ranges. Moreover, it turns out that superconducting quantum interference devices (SQUIDs) can be used as intrinsically switchable meta-atoms. Lazarides and Tsironis have theoretically shown [1] that the intrinsic nonlinearity of a SQUID leads to multi-stable dynamical states in a metamaterial, each of them associated with a specific value and sign of the magnetic susceptibility. We have experimentally detected these states [2] and demonstrated that it is possible to switch between them by applying nanosecond-long microwave pulses, in addition to the microwave probe signal. The potential application of this effect is a wireless (all-"optical") switchable metamaterial based on SQUID type meta-atoms. More recently, we hav! e explored the nonlinearity of SQUID metamaterials by performing a two-tone resonant spectroscopy [3]. The small-amplitude response of the metamaterial under strong driving by a microwave pump signal leads to pronounced oscillations of the metamaterial transparency band. The response to the probe signal also displays instabilities and sidebands. The theoretical analysis of these observations is in good agreement with our experimental results.

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Contact Interactions in Heterostructures: A Squeezed Limit

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The heterostructures composed of two and three parallel plane layers are studied in the squeezed limit as both the thickness of the layers and the distance between them simultaneously tend to zero. The presence of a squeezed prewell in the potential profile in the system is shown to be crucial for the appearance of non-zero tunneling transmission through zero-thickness heterostructures. The typical example of such a system is the bilayer for which the squeezed potential profile is the first derivative of Dirac's delta function. It is demonstrated that the squeezed potentials are not required to have a limit in the sense of distributions and there exists a whole family of well-defined single-point interactions of one-dimensional Schroedinger equations for which the resonant tunneling transmission occurs at some hypersurfaces in the space formed by the layer strength constants (curves for a bilayer on the 2D plane and surfaces for a trilayer in the 3D space). These hypersurfaces form a countable (discrete) resonance set on which the transmissivity is non-zero, whereas beyond this set the system is fully opaque satisfying the Dirichlet boundary conditions at both the sides of the potential. The conditions for the resonant tunneling and the reflection-transmission coefficients for these interactions are computed explicitly. It is shown that for a given multilayer system, the resonance set crucially depends on the way of one-point shrinking. One these ways results in the appearance of a bound state in the derivative delta potential. The notion of point (contact) interactions with bias potentials is introduced. The transmission matrix and reflection-transmission coefficients for biased point systems are interpreted and computed asymptotically. References below exemplify the subject.

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