Contributed Talks and Posters
Dynamics Days 2018

Giulia Ruzzene

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Contributed talks:

1. *Rate-induced transitions for parameter shift systems with non-equilibria attractors*
Hassan M. Alkhayuon, Peter Ashwin
Affiliation: Center for Systems Dynamics and Control, University of Exeter, UK
Abstract. In comparison with equilibrium attractors, rate-induced transitions from attractors that are not simply equilibria are less examined. For a specific class of systems with a parameter shift between two autonomous systems, we consider how the breakdown of the quasistatic approximation for attractors can lead to rate-induced transitions, where nonautonomous instability can be characterised in terms of a critical rate of the parameter shift. We find a number of new phenomena for non-equilibrium attractors: weak tracking where the pullback attractor of the system limits to a proper subset of the attractor of the future limit system, partial tipping where certain phases of the pullback attractor tip and others track the quasistatic attractor, invisible tipping where the critical rate of partial tipping is isolated and separates two parameter regions where the system exhibit tracking. We consider weak tracking for nonautonomous Rössler system, showing that there are infinitely many critical rates at each of which the point pullback attractor of the system tracks an embedded unstable periodic orbits of the future chaotic attractor.

2. *Active swimmers in an axisymmetric vortex flow: from Hamiltonian dynamics to clustering*
Jose Agustin Arguedas Leiva
Affiliation: Max Plank Institute for Dynamics and SelfOrganization, Goettingen, Germany
Abstract. Active swimmers in turbulent flows have attracted much attention recently. One prominent example is phytoplankton in the ocean, which non-trivially interact with small-scale turbulence. This interaction gives rise to many interesting phenomena such as preferential clustering. Many fundamental questions regarding these phenomena, like their dependence on parameters such as shape or swimming velocity, remain open. As a prototypical example we study the dynamics of active swimmers in a two-dimensional axisymmetric flow. We comprehensively characterize the relevant phase space. For spherical swimmers, we uncover the underlying Hamiltonian structure. For more general shapes we find that the topology of the phase space is preserved, but the Hamiltonian structure is broken. As a consequence preferential clustering can occur. This example of active swimmers in a simple flow field yields new insights into the understanding of swimmer dynamics and may guide investigation of the clustering mechanisms in realistic turbulent flows.

3. *Multilayered flows in the shallow water limit: dynamics and loss of hyperbolicity in a mixed type PDE*
Francisco de Melo Virissimo, Paul A. Milewski
Affiliation: Department of Mathematical Sciences, University of Bath, UK
Abstract. In this presentation, we will formulate and discuss the problem of density stratified interfacial flows in the shallow-water limit. This type of flow occurs in nature with the atmosphere and ocean as prime examples. Mathematical studies of these are particularly important, since wave

motion tends not to be resolved by most numerical climate models due to their fast scales, and thus need to be understood and parameterized. For example waves may break and dissipate energy or mix the underlying fluids and affect the medium in which they are propagating. Consequently this research will both increase the understanding of internal waves, and have an impact on future climate models. We will focus our attention on the two and three-layer flows, without the so-called Boussinesq approximation which requires small density differences. This is a simplified model for geophysical situations, but it is not too simplified: the model has both barotropic (fast waves affecting the whole fluid uniformly) and baroclinic modes (slower waves with more internal structure). The governing equations will be derived and the dynamics of their solutions will be studied from both analytical and numerical points of view, particularly the issue of whether the solutions maintain hyperbolicity (i.e. wave-like behaviour). Explicity criteria for transition to the elliptic regime will be provided using new dynamical system techniques. The existence of invariant hyperbolic regions will be proven and examples will be constructed using the so-called simple waves. These invariant regions are very important as they guarantee the well-posedness of the problem (in the sense of J. Hadamard). In addition, some of the techniques presented can be also applied to more general mixed-type systems of PDEs. Extensions and future work will be presented at the end.

4. *Load dependence of power outage statistics*
Soumyajyoti Biswas
Affiliation:
Abstract. The size distributions of power outages are shown to depend on the stress, or the proximity of the load of an electrical grid to complete breakdown. Using the data for the U.S. between 2002-2017, we show that the outage statistics are dependent on the usage levels during different hours of the day and months of the year. At higher load, not only are more failures likely, but the distribution of failure sizes shifts, to favor larger events. At a finer spatial scale, different regions within the U.S. can be shown to respond differently in terms of the outage statistics to variations in the usage (load). The response, in turn, corresponds to the respective bias towards larger or smaller failures in those regions. We provide a simple model, using realistic grid topologies, which can nonetheless demonstrate biases as a function of the applied load, as in the data. Given sufficient data of small scale events, the method can be used to identify vulnerable regions in power grids prior to major blackouts.

5. *Volume explored by a branching random walk on general graphs*
Ignacio Bordeu
Affiliation: Department of Mathematics, Imperial College London
Abstract. The volume explored by a branching random walk is of fundamental importance in a wide range of systems, such as chemical reactions and disease propagation. Exact results are limited to one dimension. The major difficulty is to take into account fluctuations and correlations, which dominate the dynamics in the critical regime. In this talk, I will show how through a field theoretical approach, we can calculate the scaling exponents and universal amplitudes and can be carried out to all orders, producing exact results. Our findings can be applied directly to the study of branching processes, such as bacterial growth and viral spreading in two and three-dimensional matrices, as well as in complex networks. We support our findings by Monte-Carlo simulations above and below the critical dimension dc = 4, as well as on fractal lattices and in random networks.

6. *Control of biodiversity in evolutionary dynamics: extension to higher dimensions*
Jens Christian Claussen
Affiliation: Aston University, Birmingham, UK
Abstract. Cyclic dominance, as observed in biology and socio-economic systems, has frequently been investigated in its role towards stabilization of diversity of strategies [PRL 100, 058104], and it has been shown that the introduction of a parameter in the payoff matrix can lead to a stabilization of the symmetric state of coexistence. Recently, we had introduced a feedback control method

which utilizes a feedback term derived from a conserved property of motion of the case of a neutral oscillation. This mechanism was discussed, analyzed and numerically demonstrated explicitly for the cyclic rock-paper-scissors game. Here, we discuss the generalization to cyclic dominance of M strategies and their implications. First, it is observed that the straightforward generalization leads again to payoff functions with polynomial degrees up to third order, multiplied by the feedback term which in this case is of order M, resulting in characteristic polynomials of order $2 \cdot (M + 2)$, compared to order 4 without control, prohibiting closed eigenvalue expressions even for the fixed point stability. To circumvent this, alternative feed- back functions are introduced which allow for lower orders. Finally, we discuss the applicability of this approach to biological populations.

7. *Symmetric calorons and the rotation map.*
Joshua Cork
Affiliation: University of Leeds
Abstract. Calorons are finite-action, anti-self-dual connections on $\mathbb{R}^3 \times \mathbb{S}^1$, and belong to a family of objects known as topological solitons. Related to calorons are other solitons, specifically instantons on $\mathbb{R}^4$, and monopoles on $\mathbb{R}^3$ – indeed, one perspective of calorons is that they are formed of N monopole constituents, where N is the rank of the gauge group. These solitons have enjoyed an enormous amount of attention from both mathematicians and physicists alike, and of particular interest are their symmetries, and how they can be exploited for explicit construction, and understanding of the underlying geometry. In this talk I shall describe various methods for approaching this topic in the context of calorons, with emphasis on a special isometry called the rotation map, which may be understood as a cyclic permutation of the constituent monopoles.

8. *Melody prediction and composition using complex networks*
Débora Cristina Corrêa
Affiliation: Department of Mathematics and Statistics - University of Western Australia, Nederlands, WA 6009 Australia
Abstract. Mathematical modeling of music and its algorithmic composition are well-established fields. We are interested in the algorithmic extraction of a dynamical model which is capable of representing and recreating pieces of music in the form of symbolic time series. While the general idea has already been developed decades ago, the capability of different models to preserve patterns in music, particularly when imitating a style or composer, demands closer examination. In this study, melodies are handled as time series originating from dynamical processes, and are represented as complex networks. We establish a one-step prediction task to investigate the capability of a stochastic model described by a Markov Chain to preserve temporal structures characteristic for the style or composer. Markov chains have been extensively used in various other forms of music modelling, but a systematic quantification of the quality of the prediction and generalization of such models has hardly been addressed. Besides training and testing the models on individual melodies, their generalization capacity is studied by cross-prediction between different songs, providing information about the level of individuality of the songs and similarity between styles. We finally present examples of melodies which are generated by the trained models operating autonomously.

9. *Inhomogeneities and caustics in the sedimentation of noninertial particles in incompressible flows*
Gabor Drotos, Pedro Monroy, Emilio Hernandez-Garcia, Cristobal Lopez
Affiliation: Insituto de Fisica Interdisciplinar y Sistemas Complejos (UIB-CSIC), Palma de Mallorca, Spain
Abstract. In an incompressible flow, fluid density remains invariant along fluid element trajectories. This implies that the spatial distribution of non-interacting noninertial particles in such flows cannot develop density inhomogeneities if they are not already introduced in the initial condition. However, in certain practical situations, density is measured or accumulated on (hyper-) surfaces of dimensionality lower than the full dimensionality of the flow in which the particles move. An example is the observation of particle distributions sedimented on the floor of the ocean. In such cases, even if noninertial particles are distributed uniformly over a finite support in an incompressible flow,

advection in the flow will give rise to inhomogeneities in the observed density. In this paper we analytically derive, in the framework of an initially homogeneous particle sheet sedimenting towards a bottom surface, the relationship between the geometry of the flow and the emerging distribution. From a physical point of view, we identify the two processes that generate inhomogeneities to be the stretching within the sheet, and the projection of the deformed sheet onto the target surface. We point out that an extreme form of inhomogeneity, caustics, can develop for sheets. We exemplify our geometrical results with simulations of particle advection in a simple kinematic flow, study the dependence on various parameters involved, and illustrate that the basic mechanisms work similarly if the initial (homogeneous) distribution occupies a more general region of finite extension rather than a sheet.

10. *Complexity of the driven snapshot attractors considering the ergodicity in the parameter space*
Agnes Fülöp
Affiliation: Ágnes Fülöp Department of Computer Algebra, Eötvös Loránd University of Sciences, 1117 Budapest Pázmány P. street 1/C. Hungary
Abstract. The complexity C that reasons a given time series of measurement, plays important role of the statisti al physi s (1), information theory (2), mathematics (3). We consider the time sequences of measurements between chaotic and non-chaotic regions (4), it is described by statistical complexity C(H, D) (5,6), which depends on the entropy H and the disequilibrium D on a finite N-system of the manifold of trajectories. The characterization of the more complicated dynamical structures and be described by the complexity C(H, D) considering the probability distribution of the finite measured systems. Although the Kolmogorov-Sinai entropy provides the tendency of the flow (7), but the complexity C allows to determine the localization of the strange attractor, the transition states and periodic motion on the parameter space near to the intermittent region thinking of the ergodicity. The snapshot attractors can be applied to study the model of global atmospheric circulation (8,9) using a driving system. This structure of a driven model shows either simple or fractal structure. We researched the chaoticity of this model by numerical approximation to analyze the statistical complexity of the time dependent attractor.
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11. *Chaotic attractors in low-dimensional systems of globally coupled identical phase oscillators*
Evgeny Grines (1), Alexey Kazakov, (1,2) Grigory Osipov (1), Igor Sataev (3)
Affiliation: (1) Lobachevsky State University of Nizhni Novgorod, 23 Gagarin av., Nizhny Novgorod 603950, Russia (2) National Research University Higher School of Economics, 25/12 Bolshaya Pecherskaya Ulitsa, 603155 Nizhny Novgorod, Russia (3) Kotelnikov's Institute of Radio-Engineering and Electronics of RAS, Saratov Branch, Zelenaya 38, Saratov, 410019, Russia
Abstract. Systems of globally coupled phase oscillators can demonstrate a variety of complex behaviours. If oscillators and interactions between them are identical, a coupling function is a primary source of complexity. It was shown that chaotic attractors emerge when a coupling function is non-Kuramoto: a biharmonic coupling (also called Kuramoto-Daido or Hansel-Mato-Meunier) leads to chaos in the case of five oscillators (1) and a system of four oscillators exhibits chaotic dynamics when non-pairwise interactions are introduced into coupling (2). Here we discuss some aspects of the transition to chaos in these particular examples. For the system of five phase oscillators, we

show that some transitions follow the scenario of the creation of a discrete Shilnikov attractor (3) - a homoclinic attractor based on a saddle-focus fixed point with a two-dimensional unstable manifold. In the system of four phase oscillators, we have found examples of heteroclinic cycles similar to ones analyzed in (4). Such heteroclinic cycles consist of saddle-sink connections on invariant planes alternating with saddle-saddle connections. Similar to the homoclinic loop to a saddle-focus, they imply a presence of countably many saddle periodic orbits. As a result, these heteroclinic cycles can organize complex dynamics. We also discuss interrelation between symmetries of this system and its possible homoclinic and heteroclinic structures.

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12. *Critical Transitions and Perturbation Growth Directions*
Nahal Sharafi, Marc Timme,Sarah Hallerberg
Affiliation: Hochschule für Angewandte Wissenschaften Hamburg, Fakultät Technik und Informatik, Department Maschinenbau und Produktion, Hamburg, Germany
Abstract. Critical transitions occur in a variety of dynamical systems. Here we employ quantifiers of chaos to identify changes in the dynamical structure of complex systems preceding critical transitions. As suitable indicator variables for critical transitions, we consider changes in growth rates and directions of covariant Lyapunov vectors. Studying critical transitions in several models of fast-slow systems, i.e., a network of coupled FitzHugh-Nagumo oscillators, models for Josephson junctions, and the Hindmarsh-Rose model, we find that tangencies between covariant Lyapunov vectors are a common and maybe generic feature during critical transitions. We further demonstrate that this deviation from hyperbolic dynamics is linked to the occurrence of critical transitions by using it as an indicator variable and evaluating the prediction success through receiver operating characteristic curves. In the presence of noise, we find the alignment of covariant Lyapunov vectors and changes in finite-time Lyapunov exponents to be more successful in announcing critical transitions than common indicator variables as, e.g., finite-time estimates of the variance. Additionally, we propose a new method for estimating approximations of covariant Lyapunov vectors without knowledge of the future trajectory of the system. We find that these approximated covariant Lyapunov vectors can also be applied to predict critical transitions.

13. *Numerical simulations of coupled fluid sloshing in finite- depth with vessel undergoing horizontal motion*
Ying Hao Huang
Affiliation: Department of Mathematics University of Surrey, Guildford, United Kingdom
Abstract. A Tuned Liquid Damper (TLD) is a damping device used to mitigate wind and earthquake induced vibrations in tall buildings and other large structures. It consists of a vessel containing a fluid which is attached to a solid wall through a spring. In this talk we derive a numerical scheme that is based on Ardakani [EJM, 21, 479-517 (2010)] where it is assumed the fluid within the vessel is in the shallow-water limit. We have extended this concept to incorporate fluid in finite-depth. The governing fluid equations are Euler's equations in the Lagrangian particle path setting, which are transformed to a set of Hamilton's equations. The scheme is symplectic which means it preserves the Hamiltonian structure of the system. In other words, the total energy is

conserved in the absence of external force. The work is very recent and the numerical scheme is still being fine-tuned.

14. *Bifurcation analysis of a mode-locked V-shaped cavity laser*
J. Hausen, S. Meinecke, K. Lüdge
Affiliation: TU Berlin, Institute for Theoretical Physics, Hardenbergstrasse 36, 10623 Berlin, Germany.
Abstract. We investigate the effect of the external cavity geometry on the output of a passively mode- locked vertical-external-cavity surface emitting laser (VECSEL). We derive a multi-delay differential equation model based on the travelling-wave equations within a semiconductor medium, and analyse the dynamics of the device. The gain chip is placed in between an out-coupling facet and a saturable-absorber so that pulses pass the gain twice per round-trip. The changes in dynamics are investigated by applying numerical calculations as well as path-continuation methods to determine the underlying bifurcations. Our investigations indicate that by repositioning the gain chip, the laser can be operated in different stable regions e.g. fundamental mode-locking, higher harmonic mode-locking or double-pulse mode-locking. Complex dynamics and chaos are evident in between the regions of stable operation.

15. *Possible non-Markovian nature of diffusive process of virus capsid*
Yuichi Itto (1), Jens B. Bosse (2)
Affiliation:(1) Science Division, Center for General Education, Aichi Institute of Technology, Aichi 470-0392, Japan (2) Heinrich Pette Institute, Leibniz Institute for Experimental Virology, Hamburg, Germany
Abstract. Recent experimental studies (1,2) have elucidated that virus capsid, which is a protein shell surrounding viral DNA, exhibits heterogeneous diffusion in such a way that the diffusion exponent fluctuates over interchromatin corrals in a cell nucleus. Remarkably, the fluctuation distribution takes a robust Gaussian form showing anomalous diffusion as well as normal one (see Ref. (3) for its theoretical derivation). Here, the temporal property of the diffusive process over the corrals is examined in the context of a relation to be satisfied by a class of Markovian processes (4). The sojourn-time distribution of the virus capsid in the corrals, in which the Gaussian fluctuation is incorporated, is also discussed. The present result combined with the experimental data of the spatial displacement in Ref. (1) shows a possible violation of the relation and, thus, may imply non-Markovianity of the process, highlighting temporal complexity of virus-capsid diffusion in a peculiar manner.

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16. *Pattern formation in a generalized Navier Stokes model for active fluids*
Martin James
Affiliation: Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany
Abstract. Generalized Navier Stokes equations have recently been used to model active fluids such as dense bacterial suspensions. These models capture the fundamental features of active fluid dynamics - self-propulsion and alignment of its microscopic constituents - through an effective continuum theory. Such models for active fluids have been shown to exhibit a variety of ordered and disordered phases. In this contribution we explore these phases, including a square lattice state, a turbulent state and a self-organized quasi-stationary vortex crystal state preceded by a long turbulent transient. We show that the nonlinear advection plays an important role in the dynamics of this system by destabilizing the classical square lattice state, leading to a dynamic hexagonal lattice state for sufficiently strong advection. We investigate the stability of these phases as well

as the transitions between them. Our results provide insights into *turbulent pattern formation* in active systems.

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17. *Self-propelled motion of a particle above a two-dimensional plasma crystal*
Ingo Laut, Christoph Räth, Sergey K. Zhdanov, Volodymyr Nosenko, Gregor E. Morfill, Hubertus M. Thomas
Affiliation: Institut für Materialphysik im Weltraum, Deutsches Zentrum für Luft- und Raumfahrt (DLR) Weßling, Germany
Abstract. Plasma crystals consist of ordered arrangements of charged microparticles that levitate in a weakly ionized gas. Besides confining the particles, the plasma also alters the microparticle interaction, making it nonreciprocal. The nonreciprocal interactions cause interesting effects like the mode-coupling instability and the formation of particle strings or spinning particle pairs. Here, we analyze in simulations and theory the self-propelled motion of an "extra" particle floating above a two-dimensional plasma crystal. Previous experimental observations (1) showed that the extra particle is confined in a channel of two neighboring rows of particles and moves persistently through the crystal. We use the simple model of a pointlike ion wake charge to reproduce this intriguing effect in simulations. We show that the nonreciprocity of the particle interaction is responsible for a broken symmetry of the channel that enables the self-propelled motion of the extra particle (2) .

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18. *Stochastic modeling of wind speed data form an offshore platform*
Pedro G. Lind, Kristoffer Schieders, So-Kummeth Sim, Matthias Wolff, Philipp Maass
Affiliation: Fachbereich Physik, Universität Osnabrück, Germany
Abstract. Understanding short-time fluctuations of wind speed is becoming increasingly important for a better forecasting of power production by large wind turbines. Here, we present modeling approaches for time series of wind speeds, which were measured at the off-shore FINO1 research platform in the North Sea. First, we provide a statistical description of wind speed fluctuations at different heights. Secondly, we present a modelling of the time series based on ARIMA models, and evaluate their quality for increments in different time lags. We find that for hourly averaged data, wind speed forecasts are generally good. However, upon shortening of the averaging interval, forecasts become less reliable. Finally, we discuss how to combine both these approaches with power-grid models for investigating the behavior of the grid under injection of fluctuating power.

19. *The Impulse Pattern Formulation (IPF) as a model of musical instruments - Investigation of stability and limits*
Simon Linke
Affiliation: Department Media Technic of the University of Applied Science Hamburg, Hamburg, Germany
Abstract. The Impulse Pattern Formulation (IPF) is an analytical modeling approach for synergetic systems in general, motivated by research on musical instruments. Viewing musical instruments as driven by impulses which are caused by strings or reeds and which are reflected at several points in the instrument body, the formulation assumes musical instruments as self-organized systems. Then the very stable harmonic overtone spectrum, as well as the salient initial transient of musical instrument tones can be explained. Based on the assumption that the coupling of system components can be described by the interaction between individually propagating, and exponen-

tially damped impulse trains, the IPF can be described in its most simple form:

$$g = g_- - \ln\left(\frac{g_-}{\alpha}\right).$$

Adding more system components increases the number of reflection points, thus the number of terms in the argument of the logarithm increases. The IPF, similar to other nonlinear recursive equations, is able to produce stable states but also bifurcation and divergency. In contrast to other nonlinear functions such as the Logistic Map, the IPF does not map the unit interval to itself and does not have a local maximum between 0 and 1, but it has one or more singularities. Therefore, system predictions cannot be derived easily from knowledge on other theories, neither can the system be completely examined analytically. The influence of the number of reflection points and their potential to reflect impulses, are explored in relation to the start value, by numerical simulations. As a result, stable, instable, and bifurcating regions are identified to capture modeling capabilities of IPF. These results match tone generation in musical instruments.

20. *Tuning critical excitations in stiff cardiac models*
Cristopher Marcotte
Affiliation: Living Systems Institute, University of Exeter, United Kingdom
Abstract. Excitable models of cardiac tissue typically couple dynamical features on wildly disparate spatial and temporal scales, leading to patterns which resist classical methods of analysis. Semi-analytical techniques [Bezekci et al. (PRE, 2015)] may address this difficulty and characterize excitability properties of cardiac models, for which stiff models present a numerical challenge. An essential ingredient of these techniques is the stability spectrum of the simplest coherent structures produced by these models. I will discuss techniques for computing these solutions in several stiff models of cardiac tissue dynamics and use their stability characteristics to predict excitability properties of the model. Additionally, I explore how these techniques are applied to models with non-Tikhonov features and the application of these techniques to understanding conduction block.

21. *Finite-Time Stabilisation of Phase Dynamics*
Julian Newman, Maxime Lucas, Aneta Stefanovska
Affiliation: University of Lancaster, United Kingdom
Abstract. Stability of dynamics is often analysed from an infinite-time point of view, e.g. by asymptotic stability or the sign of maximal Lyapunov exponents. In this talk, we will present a stabilisation phenomenon for finite-time non-autonomous differential equations on the circle, where stability is assessed in terms of finite-time contraction factors, or equivalently, finite-time Lyapunov exponents. We will observe both that the phenomenon holds for systems where there is no natural way to extend the dynamics to infinite time, and that the phenomenon is likely to be missed by a traditional asymptotic approach even for quasiperiodic systems where asymptotic analysis is possible.

22. *Short-time evolution of statistics of random waves in one-dimensional semi-classical nonlinear Schrödinger equation*
Giacomo Roberti
Affiliation:
Abstract. We present here a work on the statistical properties of integrable turbulence. In particular we investigate partially coherent waves having Gaussian statistics, and we examine the short time evolution according to the one-dimensional nonlinear Schrodinger Equation (1D-NLSE) in the focusing and defocusing regime. Using a semiclassical approach we are able to derive a formula for the early development of the fourth order moment of the amplitude of the field. Moreover, we performed numerical simulation to verify the theoretical prediction. In the short time regime, the results already present the main features of the appearance of the so-called heavy (resp. low) tails of the amplitude PDF emerging in the focusing (resp. defocusing) regime of the 1D-NLSE.

23. *Extreme events in delay coupled systems: Generating mechanism, precursors and basins of attraction*
Arindam Saha, Ulrike Feudel
Affiliation: ICBM, University of Oldenburg, Carl von Ossietzky Strasse 9-11, 26129 Oldenburg, Germany
Abstract. While rare, recurrent, irregularly spaced yet impactful events - also known as extreme events - might be manifested in different systems in different ways, previous research works have identified a few underlying mechanisms which may generate such events from as dynamical systems point of view. These generating mechanisms include the presence of noise, external forcing and inhomogeneity among nodes of a network. In the current work, we present time-delay as another mechanism through which extreme events may be generated and study their salient features in detail. To this end, we show that in a system of two identical FitzHugh-Nagumo oscillators coupled to each other by multiple delay-diffusive couplings, extreme events can be generated in parameter regimes sandwiched between a period adding cascade and a period doubling cascade. Due to infinite dimensions of the phase space and the presence of an invariant synchronization manifold, the system studied, exhibits rich and interesting dynamical features. In contrast to the other known mechanisms of extreme event generation, the extreme events generated in this system appear in two distinct categories - synchronous and asynchronous - depending on the distance of the trajectory relative to the invariant synchronization manifold. We also identify the role of the invariant sets on this manifold in the long transience and the observed in-out intermittency. We also present our investigations regarding the basin structure of the system when multiple attractors are present simultaneously. Our results show that if one of the attractors present in such a parameter regime corresponds to extreme events, the basins are riddled. In such a scenario, the phase space can be partitioned into pure and mixed regions, where initial conditions in the pure regions certainly avoid the generation of extreme events, while initial conditions in the mixed region may or may not exhibit such events. This implies that any tiny perturbation of initial conditions in the mixed region could yield the emergence of extreme events because the latter state possesses a riddled basin of attraction.

24. *Characterization of isochronous orbits in time delayed feedback oscillator model*
Sandip Saha, Gautam Gangopadhyay
Affiliation: S. N. Bose National Centre For Basic Sciences, Kolkata-700106, India
Abstract. Starting from the definition of isochronous oscillation whose frequency is independent of amplitude, we have shown that they can be of limit cycle, center or center-type oscillations. For a delayed model, we have given approximate solution from a multi-scaled perturbation theory in terms of periodic orbits. This solution is utilised to characterise the size as well as the approach to steady state dynamics due to parametric excitation.

25. *Self-excited, hidden oscillations, symmetry breaking effects in a parametric simple pendulum*
J.C. Sartorelli (1), G.I. Depetri (1), F.A.C. Pereira (1), B. Marin (1), M.S. Baptista (1,2)
Affiliation: (1) Universidade de Sao Paulo, Brazil (2) University of Aberdeen, UK
Abstract. Our aim is to study the resonances characteristics of a parametric simple pendulum when we let the pivot pendulum to oscillate with an angle ϕ in relation with the vertical, for $\phi = 0$ as well as for $\phi \neq 0$. The pendulum pivot oscillates harmonically as $S(t) = A\cos(2\pi f_p t)$, with amplitude A and frequency f_p that are the control parameters, and the resonances correspond to the pendulum oscillations with period $T_n = nT_p = n/f_p$. The equation of motion is given by:

$$\ddot{\theta} = -\sin\theta - [P\cos(\Omega_p t)\sin(\theta - \phi) + \beta\omega], \quad (1)$$

where $\Omega_p = \frac{\omega_p}{\omega_0}$, $P = \frac{\omega_p^2 A}{g}$, $\omega_p = 2\pi f_p$,$\omega_0 = 2\pi f_0$, $\beta = \frac{b}{\omega_0}$, f_0 is the natural pendulum frequency, b is the dissipation parameter, and g is the gravitational acceleration. For $\phi = 0$, the hidden oscillations related to the odd resonances $n = 3, 5, \ldots$ are not predictable by the first order Melnikov's method. But we could find numerically and experimentally degenerate period-3 resonances by making high

resolution basins of attraction. The degenerate period-3 resonances follow the same loci of saddle-node bifurcations in the parameter space (Ω_p, P), calculated by numerical continuation method. We also found only numerically period-5 and period-25 oscillations. Through simulations we also observed even resonances $n = 2$ and 4, related respectively to period doubling (self-excited) and saddle-node bifurcations (hidden oscillations). For small tilt excitation $\phi = \frac{4\pi}{180}$, the inversion system symmetry is broken so the degeneracy of the period-3, they do not follow anymore the same loci of saddle-node bifurcations(hidden oscillations) in the parameter space (Ω_p, P). For $\phi = \pi/8$, we observed experimentally self-excited oscillations by constructing bifurcation diagrams keeping fixed A=2.02cm and swapping the excitation frequency from 0.8 Hz up to 12HZ, so the sequence of bifurcations were observed: first a bubble of bifurcation in which $T = T_p \rightarrow T_p/2 \rightarrow T_p$, followed by a saddle-node bifurcation in which the oscillations are $T_1 = T_p$ after a period doubling bifurcation $T_2 = 2T_p$ occurs. From $f_p \approx 4.15Hz$ to $12Hz$ only a period-1 ($T_1 = T_p$) is observed. We observed experimentally the hidden oscillations, T_3, T_4 and T_5, by setting the frequencies f_p according to the simulated bifurcation diagram and adjusting manually the pendulum initial conditions until the hidden oscillation attractor was found.

26. *Bifurcations of phase portraits of pendulum with vibrating suspension point*
K. Sheng
Affiliation: University of Loughborough, UK
Abstract. We consider a simple pendulum whose suspension point undergoes fast vibrations in the plane of motion of the pendulum. The averaged over the fast vibrations system is a Hamiltonian system with one degree of freedom depending on two parameters. We give complete description of bifurcations of phase portraits of this averaged system.

27. *Modular networks with bipartite communities; A model for the spread of sexually transmitted diseases in a population*
Aradhana Singh, Sitabhra Sinha
Affiliation: The Institute of Mathematical Sciences, C.I.T. Campus - Taramani, Chennai, 600 113 India
Abstract. The realization that the connection topology of social networks plays a crucial role in determining the spread of infectious diseases has resulted in an enormous growth of studies in this topic, both theoretical and empirical (1). One of the specific features investigated in this context is the impact on epidemics of mesoscopic structural features, such as the organization of networks into communities (characterized by dense intra-connectivity and relatively sparse inter-connectivity) (2). For instance, it has recently been shown that an optimal level of modularity in the contact network can significantly promote the persistence of recurrent epidemic outbreaks (3). However, if one considers the class of sexually transmitted diseases (STDs), we need to necessarily take into account a further structural feature, viz., the segregation of each community into male and female subpopulations. Depending on the sexual orientation of the individuals being considered, interactions could be primarily between the two subpopulations resulting in a nearly bipartite organization in each community. This will lead to a connection topology that is modular at one scale, and anti-modular in another. We present a model for such an interaction topology having tunable parameter r, i.e., the ratio between intra- and inter-modular connection densities. This allows us to investigate the behavior of spreading processes in such networks as a function of their mesoscopic organization keeping the connectivity (average degree) fixed. Elucidating the properties of this model class of networks allows us to obtain a number of results pertinent to understanding the spreading of STDs. In particular, we find the occurrence of diffusion with three distinct classes of time-scales, viz. that governing the spreading within each gender in a community, between two genders in a community and globally over the entire population, respectively. We connect this result to the characteristic spectral signature of the corresponding Laplacian matrix. While modular networks have earlier been associated with two distinct dynamical time-scales (viz., intra- and inter-modular) (4), we believe that the occurrence of an additional dynamical time-scale in the case of social networks pertinent for STDs would have significant consequences for understanding their spreading dynamics.

As STDs constitute a persistent challenge to public health, especially after the advent of HIV AIDS in the 1980s, understanding the distinct pattern of spreading of such diseases may be an important step towards their eventual control and containment (5).

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28. *Extreme Value Laws for Maxima on Cantor sets*
Jorge Soares
Affiliation: Faculty of Science, University of Porto
Abstract. We analyse stochastic processes arising from dynamical systems by evaluating an observable function along the orbits of the system. We consider that the observable function is maximised at a Cantor set and the objective is to show the existence of an Extreme Value Law for the corresponding stochastic process. The geometric structure of the maximal set and its dynamical preimages play a crucial role in the determination of the type of limiting law. In particular, we observe a link between the Hausdorff Content of the maximal set and the Extremal Index, which measures the intensity of clustering of extreme events.

29. *Disturbances compensation for dynamical systems with multiple input delays*
Salma Souhaile
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Abstract. In this work, we investigate the compensation problem of known or unknown disturbances for a class of distributed systems with multiple input delays given as follows :

$$\begin{cases} \dot{x}(t) & = Ax(t) + \sum_{i=1}^{M} B_i u_i(t-h_i) + f(t);\ 0 < t < T \\ x(0) & = x_0; \\ u_i(t) & = 0; t \in [-h_i, 0]. \end{cases}$$

We show how to remedy any disturbance effect with a convenient choice of the control operator through the observation. The developments are based on semigroups theory and using an extension of Hilbert Uniqueness Method. An application to hyperbolic systems is presented. The usual case of sensors and actuators is examined and numerical simulations are also given.

30. *A Bifurcation Analysis of an Open Loop Internal Combustion Engine*
Shaun Smith, James Knowles, Byron Mason
Affiliation: Department of Aeronautical and Automotive Engineering, Loughborough University, UK
Abstract. The process of engine mapping in the automotive industry identifies steady-state engine responses by running an engine at a given operating point (speed and load) until its output has settled. While the time simulating this process for one set of parameters is relatively short, the cumulative time to map all possible combinations becomes computationally inefficient. Tools from bifurcation theory, such as numerical continuation, offer a complimentary approach that could speed up the mapping process and enhance the automotive engineer's understanding of an engine's underling dynamics behaviour. By adapting a simplified engine model governed by three first order non-linear differential equations, we present a two-parameter bifurcation study to investigate the engine's open-loop steady-state dynamic behaviour. Using 'throttle' and 'demand load torque' as continuation parameters, several co dimension 1 and 2 bifurcations (including Hopf and Bogdanovans-Takens bifurcations) are observed locally in the engine's state-parameter space.

These bifurcations are shown to correspond to key physical properties of the open-loop system, such as fold bifurcations corresponding to the points where the engine may stall, and unstable equilibrium branches bounding a region of the demand torque available at any given throttle angle. The techniques used in this case study demonstrate the efficiency a bifurcation approach has at highlighting different regions of dynamic behaviour in the engine's state-parameter space. The information obtained from the bifurcation analysis could be used to inform the design of engine control strategies.

31. *Coupling between nucleation and chemical process in iodine oxidation reaction*
Kristina Stevanović, Itana Nuša Bubanja, Dragomir Stanisavljev
Affiliation: Faculty of Physical Chemistry, University of Belgrade, Belgrade, Serbia
Abstract. The oxidation of iodine to iodate with hydrogen peroxide is the less investigated part of the Bray-Liebhafsky (BL) oscillatory reaction (1,2). From long time ago it is considered to be a most important problem to the solving of the mechanism of the entire BL reaction as well as other oscillatory reactions which include iodine species. Study of iodine oxidation therefore can lead to better understanding of these complex systems which is still unresolved problem despite of many investigations in the last century. It is well-known that iodine oxidation reaction, beyond BL system is accompanied by more or less nonreproductive induction period indicating certain activation energy of the whole process. Induction period may be considerably shortened by addition of iodate (3) or Ag^+ (4) and surprisingly by controlling escape of oxygen from the mixture (5). The very mild mixing of the solution increases enormously standard deviation of induction times indicating possibility of coupling chemical reactions and heterogeneous effects of gas formation (6). Despite of the large scattering of data in presence of mixing, in our present experimental study, influence of addition of the small amount of inert glass powder into the reaction mixture on induction period was examined. Experiments were traced potentiometrically at constant temperature $T = 27\ C$, with the initial reactants concentrations: $[H_2SO_4]_0 = 8.316 \times 10^{-1} M$, $[I_2]_0 = 8.0 \times 10^{-4} M$ and $[H_2O_2]_0 = 1.98 \times 10^{-2} M$. Mixing rate was $\sigma = 100\ rpm$. Average size of the glass particle was in range from 0.8 to 10 μm peaked sharply to 1 μm. Addition of inert glass powder notably decreased and unified reaction induction periods. In effect, inert glass annulled the effect of mixing on the reaction dynamics. This strongly suggests the presence of some nucleation processes in the iodine oxidation reaction mechanism. Opposed effects of mixing and inert glass addition emphasizes strong energetic coupling between nucleation phenomena and chemical reactions in the process of iodine oxidation. This will open new point of view on the mechanism of investigated process and probably on a class of chemical oscillators producing gaseous phase.

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32. *Chaos as an early warning signal for desertification in water-limited vegetation*
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Affiliation: (1) Department of Physics, Ben-Gurion University of the Negev, Beer Sheva 84105, Israel (2) Department of Solar Energy and Environmental Physics, Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede Boqer Campus, 84990, Israel (3) Mitrani Department of Desert Ecology, BIDR, Ben-Gurion University of the Negev, Sede Boqer Campus 84990, Israel
Abstract. Understanding how different plant species respond to changes in the abiotic environment is a fundamental question in ecology. To address this question, we study a mathematical model with seasonal rainfall periodicity that links biomass production to environmental conditions through the ability of plants to capture a limited water resource. We study a mathematical model for plant functional groups that make different trade-offs between investment in growth vs investment in defense mechanisms to increase tolerance to water stress. In addition, our model takes into account the penetration and distribution of water in two soil layers, assuming that evaporation occurs only in the upper layer and water uptake by plant roots occurs only in the lower layer. We observe that under these conditions there are damped oscillatory modes in the system, which are pumped by the annual rainfall periodicity and lead to sustained resonant oscillations. The existence of oscillations can have significant ecological implications. We find that species that invest mostly in growth have higher oscillation amplitudes and go through earlier collapse to bare soil as the precipitation rate is decreased, compared to species that invest mostly in defense mechanisms. We further find that the collapse to bare soil is preceded by a cascade of period-doubling bifurcations and the onset of chaos. We suggest that the appearance of period doubling followed by chaos can serve as an early warning signal for desertification.

33. *Emergence of quasi-equilibrium and slow relaxation to equipartition in heterogenous Hamiltonian dynamical systems*
Tatsuo Yanagita
Affiliation: Osaka Electro-Communication University
Abstract. We study relaxation to equilibrium in a heterogenous Hamiltonian dynamical system so called bead-spring model in solvent. The system has two distinct time scales, i.e, fast vibration of bonds between beads and a typical time scale of the collision between the bead and solvent. In the course of the relaxation to equilibrium, we found the following phenomena: i) the emergence of quasi-equilibrium state which comes from effective "freezing" of the high frequency degrees of freedom, ii) induction from the quasi-equilibrium to equilibrium, iii) slow relaxation to equilibrium and the relaxation time obeys Boltzmann-Jeans law.

34. *The structure of complex neural networks and its effects on learning*
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Affiliation: (1) Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany (2) Harvard Medical School, Boston, MA, USA (3) Tongji University, Shanghai, China
Abstract. Reservoir Computing (RC) is one of the rare computing paradigms which can be used both as a theoretical neuroscience model (2) and as a machine learning tool (1). The key feature of the RC paradigm is its reservoir a directed and weighted network that represents the connections between neurons. Despite extensive research efforts, the impact of the reservoir topology on the RC performance remains unclear. Here we explore this fundamental question and show, both analytically and computationally, how structural features determine the type of tasks that these recurrent neural networks can perform. We focus on two network properties: First, by studying the correlations between neurons we demonstrate how the degree distribution affects the short-term memory of the reservoir. And second, after showing that adapting the reservoir to the frequency of the time series to be processed increases the performance we demonstrate how this adaptation is dependent on the abundance of short cycles in the network. Finally, we leverage those results to create an optimization strategy to improve time series forecasting performance. We validate our results with various benchmark problems, in which we surpass state-of-the-art reservoir implementations. Our approach provides a new way of designing more efficient recurrent neural networks and to understand the computational role of common network properties.

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35. *A Method to Find Unstable Periodic Orbits of Chaos in the Diamagnetic Kepler Problem*
Zuo-Bing Wu
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Abstract. In the semiclassical quantization of a classically chaotic system, quantum properties are connected with unstable periodic orbits of chaos. How to find all unstable periodic orbits of chaos is an important problem in nonlinear dynamics. Symbolic dynamics can provide a precise depiction of the unstable periodic orbits. In this presentation, the diamagnetic Kepler problem (DKP), i.e., a hydrogen atom moving in a uniform magnetic field, is taken as a simple physical chaotic system. Firstly, symbolic dynamics of the DKP is established based on the lift of the annulus map, which is obtained from a Poincare section associated with the axes. The correspondence between the coding derived from this axis Poincare section is compared with the coding based on bounces. Symmetry is used to reduce the symbolic dynamics. By means of symbolic dynamics the admissibility of periodic orbits is analyzed, and the symmetry of orbits discussed. Then, a method to determine the admissibility of symbolic sequences and to find the unstable periodic orbits corresponding to allowed symbolic sequences for the DKP is proposed by using the ordering of stable and unstable manifolds. By investigating the unstable periodic orbits up to length 6, a one to one correspondence between the unstable periodic orbits and their corresponding symbolic sequences is shown under the system symmetry decomposition. This work was supported by the National Natural Science Foundation of China through the Grants Nos. 11172310 and 11472284.

Posters:

1. *Ring waves on a current with constant vorticity*
Noura Alharthi, Curtis Hooper, Karima Khusnutdinova
Affiliation: Department of Mathematical Sciences, Loughborough University, Loughborough LE11 3TU, UK
Abstract. Oceanic waves registered by satellite observations often have curvilinear fronts. We study long weakly-nonlinear ring-type waves in the presence of a horizontal current with constant vorticity, distorting the wavefronts. There exists a linear modal decomposition in the set of Euler equations describing the waves, which is used to describe the wavefronts of surface and internal ring-type waves, and to obtain a 2+1D weakly-nonlinear model for the amplitudes of the waves (1,2). Here, the general theory is applied to the case of a layered fluid with a constant vorticity current. The curvilinear wavefronts of waves in cylindrical geometry are described by the general and singular solutions of a nonlinear first-order differential equation.

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2. *Pull-back attractors and rate induced tipping in nonautonomous systems with nontrivial limit dynamics*

Hassan M. Alkhayuon, Peter Ashwin
Affiliation: Center for Systems Dynamics and Control, University of Exeter, UK
Abstract. We consider how breakdown of the quasistatic approximation for attractors can lead to rate- induced tipping, where a qualitative change in tracking/tipping behaviour of trajectories can be characterised in terms of a critical rate. Associated with rate-induced tipping (where tracking of a branch of quasistatic attractors breaks down), we find a new phenomenon for attractors that are not simply equilibria: partial tipping of the pullback attractor where certain phases of the periodic attractor tip and others track the quasistatic attractor. For a specific model system with a parameter shift between two asymptotically autonomous systems with periodic attractors, we characterise thresholds of rate-induced tipping to partial and total tipping. We show these thresholds can be found in terms of certain periodic-to-periodic and periodic-to-equilibrium connections that we determine using Lin's method for an augmented system.

3. *Combined Monte Carlo and Hydrodynamic Model of droplet Evaporation*
Mounirah Areshi
Affiliation: Department of Mathematical Science, Loughbourgh university, Loughborough, UK
Abstract. We present the steps in developing a model for liquid droplets evaporatively dewet- ting from a solid surface. The model consists of a generalised lattice-gas (Ising) model, which enables us to relate how macroscopic quantities like the contact angle and surface tension depends on the microscopic interaction parameters be- tween the particles and with the solid surface. The particle dynamics is imple- mented via a kinetic Monte-Carlo scheme, which incorporates the diffusive dynamics within the droplet and also the evaporative dynamics. We present some results for the spreading and dewetting of droplets and the effects of evaporation, and how this behaviour depends on the temperature and the microscopic interaction parameters.

4. *Separatrix crossing in rotation of a body with changing geometry of masses*
Jinrong Bao
Affiliation: Loughborough University, Loughborough, UK
Abstract. We consider free rotation of a body whose parts move slowly with respect to each other under the action of internal forces. This problem can be considered as a perturbation of the Euler-Poinsot problem. The dynamics has an approximate conservation law - an adiabatic invariant. This allows to describe the evolution of rotation in the adiabatic approximation. The evolution leads to an overturn in the rotation of the body: the vector of angular velocity crosses the separatrix of the Euler-Poinsot problem. This crossing leads to a quasi-random scattering in body's dynamics. We obtain formulas for probabilities of capture into di erent domains in the phase space at separatrix crossings.

5. *Application of System Design method to analysis of ODE based models of biochemical systems*
Wojciech Bensz
Affiliation: Silesian University of Technology, Institute of Automatic Control, Gliwice, Poland
Abstract. Qualitative analysis of dynamical systems describing biochemical reactions is still challenging despite recent progress in algebraic methods (2,3). Parameter dependence of solutions and parameter estimation are particularly challenging. One of the approaches that offer some promise is Savageau's S-system approach (6), recently employed in a software package named Design Space Toolbox v2 (5). The essence of this partly heuristic approach is to cover parameter space with subsets in which the system analyzed is "dominated" by much easier to analyze S-systems. Heuristically, the behavior of the "dominant" S-system approximates that of the complete system, in this subset. Wherever this is satisfied, the methodology allows identification and examination of qualitatively different system behaviors observed for varying values of parameters. In the current study, we investigate, using classical examples such as the systems described in (1,4,7), completeness of the coverage of the parameter space by subsets dominated by S-systems, and differences in qualitative behavior between the complete system and the dominating systems. Another aspect we consider is the connection between the "absolutely robust systems" of Shinar and Feinberg and the S-systems.

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6. *A behavioral spruce budworm predation model*
Bhagyashree Hote (1), Manas Joshi (1), Reeve Ahmed (1), Maleeha Aziz (1), Jens Christian Claussen (1,2)
Affiliation: (1) Computational Life Science Program, Jacobs University Bremen (2) Department of Mathematics, AstonUniversity, Birmingham, UK
Abstract. The spruce budworm model (1) has become a classical textbook model of predation of spruce budworms by birds (2). In the narrative of this model, the sublinear onset of predation is motivated by a metaphor that birds predate the spruce budworms only if this food source reaches awareness among the predators. Here, we explicitly introduce the fraction of birds that are aware of the additional food source as an additional dynamical variable and formulate a plausible dynamics for its increase and decay. For suitable parameters, the model shows an attracting spiral node, which results in damped oscillations of the prey density towards the fixed points, in contrast to the multistability of the original model.

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7. *Impact of particle size correlations on immiscible fluid displacement in porous media*
Oshri Borgman (1), Enrico Serge (2), Ran Holtzman (2), Lucas Goehring (3), Thomas Darwent (3)
Affiliation: (1) Department of Soil and Water Sciences, the Hebrew University of Jerusalem, Rehovot, Israel (2) Physics Services, Weizmann Institute of Science, Rehovot, Israel (3) School of Science and Technology, Nottingham Trent University, Nottingham, UK
Abstract. The displacement of immiscible fluid in a porous media is an important factor that affects processes in both industry and natural environments. Such processes include CO2 sequestration, hydrocarbon recovery and water invasion in soil. Pore and grain sizes, in particular the particle size correlation, have a significant impact on the observable behaviour of fluid displacements. We investigate the effect that varying the length scales of particle size correlation has on drainage patterns at the pore-scale. We find that as the correlation length is increased, the invaded volume and trapping fraction at breakthrough decreases.

8. *Transition curves of Mathieu-like equations via homotopy analysis and Galerkin projections*
Jeet Desai, Amol Marathe
Affiliation:
Abstract. We propose homotopy analysis method in combination with Galerkin projections to obtain transition curves of Mathieu-like equations. While constructing homotopy, we think of convergence-control parameter as a function of embedding parameter and call it a convergence-control function. Homotopy analysis provides a relation between the parameters of Mathieu equa-

tion that also includes free parameters arising from convergence-control function. We generate extra non-linear algebraic equations using Galerkin projections and solve numerically for arriving at transition curves. We demonstrate the usefulness of our method in case of three distinct versions of linear Mathieu equation by carefully choosing nonlinear and auxiliary operators. Since homotopy analysis does not demand smallness of any of the parameters, our approach has distinct advantage over perturbation methods in determining transition curves covering a large region of the parameter space. The method is applicable to a wide variety of parametrically excited oscillators.

9. *Relation between sensitive systems, topological entropy and Baire class greater than 2*
Mauricio Diaz
Affiliation: Universidad Nacional Andres Bello, Santiago, Chile
Abstract. In this article we using the concept of scrambled sets and defining a topological space (X, A), with X as a perfect, compact, metric, with T-invariant elements and T_1 regular, and a self continuous map T, we going to see cases in a general form of manifolds presents in a chaotic system (X, T) with a limit set everywhere discontinuous. For this, we use a system of n-tuple subset of X, being X a unit interval for the case of Li and X being a topological space with T as a transitive homeomorphism, based in the work on Lie-York pair. Finally we going to establish a relation between sensitive map and the presence of totally disconnected $FixT^n$ for $n \in \mathbb{Z}^+$ and we prove that the sensitive described by Devaney depend of the presence of connected $FixT^n$ and the positive topological entropy.

10. *Topological Entropy for Chaotic Systems - Researching E-system with* $h_\mu(T) \geq 0$
Mauricio Diaz
Affiliation: Universidad Nacional Andres Bello, Santiago, Chile
Abstract. In this article we research about the chaotic system seeing for Glasnert and Weiss and show that for any value of topological entropy including zero, exist a chaotic system whose system has S-property, being a perfect, T-invariant and T_1 regular, compact and metric space X and a self-continuous map T. After that we proof that any E-system with Baire class greater than 1 is a E-system only for a compact-metric manifolds M and symbolic sets S. Finally we proof that if S is an uncountable scrambled point in our E-system,then is chaotic for any value of topological entropy if and only if Baire class is greater than 2.

11. *Mode-locking in systems of globally coupled phase oscillators*
Sebastian Eydam
Affiliation: Weierstrass Institute for Applied Analysis and Stochastics, Berlin, Germany
Abstract. The dynamics of a Kuramoto-type system of globally coupled phase oscillators with equidistant natural frequencies and coupling strength below the synchronization threshold is investigated. In such systems self-organized pulsation in the mean field occurs which is usually regarded as mode locking a phenomenon much better known in the dynamics of pulsed/mode-locked lasers. The phenomenon is robust under perturbations of the natural frequencies and can also be found in large ensembles.

12. *On Algebro-Geometric Approach to Submanifolds with Flat Normal Bundle*
Evgeniy Glukhov
Affiliation: Faculty of Mechanics and Mathematics, Moscow State University
Abstract. An algebro–geometric approach to submanifolds with flat normal bundle is presented. The construction introduced in the work is a generalization of Krichever construction for orthogonal coordinate systems in flat spaces. We develop Krichever ideas and obtain formulae for embedding functions for the submanifold in terms of theta–functions of a complex curve. We also discuss some geometrical properties of the constructed submanifolds. Following the ideas of Ferapontov we describe an integrable class of hydrodynamic type system in terms of the metric and the Weingarten map of the submanifold.

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13. *Long-time evolution of pulses in the KdV equation theory in the absence of solitions: Witham method*
M. Isoard, A.M. Kamchatnov, N. Pavloff
Affiliation: LPTMS, Université Paris Sud, Orsay, France
Abstract. We consider the long-time evolution of pulses in the KdV equation theory for initial distributions which produce no solitons. We use a method designed by El and Khodorovski based on Witham modulation theory and the results are compared with numerical simulations.

14. *Stability in neutral integro-dynamic equations with delay on time scale*
Kamel Ali Khelil (1), Ahcene Djoudi (2), Abdelouaheb Ardjoun (1)
Affiliation: (1) University of Annaba, Annaba, Algeria (2) University of Souk Ahras, Souk Ahras, Algeria **Abstract.** In this work, based on the theory of calculus on time scales, we use the Krasnoselskii-Burton's fixed point theorem to obtain asymptotic stability and stability results about the zero solution for neutral integro-dynamic equation with delay on time scale. These results have important leading significance in various areas of science and engineering.

15. *Noise-indued frequency increase in synchronization of human rhythmic activities*
Wataru Kurebayashi, Masahiro Okano, Masahiro Shinya, Kazutoshi Kudo
Affiliation: Shiga University, Japan
Abstract. Okano et al. (2017) have experimentally reported that paired synchronous rhythmic finger tapping shows greater frequency increases than those for solo tapping. This experiment indicates a common mechanism underlying frequency increases in synchronization of human rhythmic activities, e.g., the performance of musical and dancing ensembles. In the present study, we mathematically model the synchronization of human rhythmic activities by a phase oscillator model with additional frequency variables. We theoretically analyze this model and prove that the frequency increase can occur ubiquitously under some weak assumptions. By numerical experiments, we demonstrate that our theory nicely predicts the frequency increase.

16. *Human pupillary light reflex model: research of complexity in a Delay Differential Equations Model*
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Abstract.

17. *The dynamics of ensemble of neuron-like elements with excitatory couplings*
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Abstract. We study the phenomenological model of ensemble of two FitzHugh-Nagumo neuron-like elements (1) with symmetric excitatory couplings. The main advantage of proposed model is the new approach to model of coupling which is implemented by smooth function that approximate rectangular function in accordance with the biological principles (2). The proposed coupling depends

on three parameters that define the beginning of activation of an element α, the duration of the activation δ and the strength of the coupling g. We observed a rich diversity of different types of neuron-like activity, including regular in-phase, anti-phase and sequential spiking activities. In the phase space of the system, these regular regimes correspond to specific asymptotically stable periodic motions (limit cycles). We also observed in the proposed model a chaotic anti-phase activity, which corresponds to a strange attractor that appears due to the cascade of period doubling bifurcations of limit cycles. In addition, we investigate in the paper an interesting phenomenon when two different chaotic attractive regimes corresponding for two different types of chaotic anti-phase activity merge in a single strange attractor. As a result, a new type of chaotic anti-phase regime appears from the collision of these two strange attractors by explosion. We also provide the detailed study of bifurcations which lead to transitions between all these regimes and detect on the (α, δ) parameter plane those regions that correspond to the above-mentioned regimes. We also show numerically the existence of bistability regions when various non-trivial regimes coexist. For example, in some regions, one can observe either anti-phase or in-phase oscillations depending on initial conditions. We also specify regions corresponding to coexisting various types of sequential activity.

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18. *Phase shift in dynamic soliton tunnelling: focusing NLS framework*
Giacomo Roberti
Affiliation:
Abstract. The framework of integrable turbulence has been recently recognised as a novel theoretical paradigm of major importance for a broad range of physical application from photonics to oceanography. In particular, in the context of nonlinear optics, the dynamics can be mathematically described by the focusing Nonlinear Schrodinger equation (NLSE). This integrable equation is known to possess soliton solutions, and a more peculiar family of breather solutions. Our work is focused on the study of the interaction between these structures. In particular, we investigate the interaction between a "trial" soliton and a broad hump that can eventually evolve into a soliton gas [1]. As was shown in [1] the macroscopic dynamics of soliton gas is determined by phase shifts occurring in two-soliton interactions. More recently, it was shown in [2], that interaction of a NLSE soliton with radiative component of the solution also leads to a phase shift, which should play a role in the full turbulent NLSE dynamics. To understand the interplay between the two phase shifts, we systematically performed a series of numerical simulations to study the delay of the moving trial soliton due to the interaction with a large hump. We investigated how the phase shift of the soliton is affected by its velocity and the initial position on the one hand, and by the soliton/radiative spectral content of the hump on the other. The curve that describes the soliton delay as function of the spectral content of the hump shows a monotonous behaviour at high velocity when the soliton content of the hump plays the dominant role in the interaction. Instead, at low velocity, the contribution of the radiative content of the hump to the interaction increases and the curve features a non-monotone behaviour with local maxima corresponding to the presence of an integer number of solitons in the hump. We compare our numerical results with the analytical predictions of [2].

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19. *Complex and Disordered patterns*
Alastair Rucklidge
Affiliation: University of Leeds
Abstract.

20. *Bifurcations of phase portraits of pendulum with vibrating suspension point*
K. Sheng

Affiliation: University of Loughborough
Abstract. We consider a simple pendulum whose suspension point undergoes fast vibrations in the plane of motion of the pendulum. The averaged over the fast vibrations system is a Hamiltonian system with one degree of freedom depending on two parameters. We give complete description of bifurcations of phase portraits of this averaged system.

21. *Stability analysis of a symmetric four-body model*
Anoop Sivasankaran
Affiliation: Department of Applied Mathematics and Sciences, Khalifa University of Science and Technology, Abu Dhabi, UAE
Abstract. The Caledonian Symmetric Four Body Problem (CSFBP) is a restricted four body system with a symmetrically reduced phase space which can be applied to study the stability and evolution of quadruple-stellar clusters and exoplanetary systems. We use a newly-developed regularization scheme to numerically investigate the hierarchical evolution of the CSFBP for a comprehensive set of orbits, including those which pass through close encounters. We numerically study the relationship between the hierarchical stability of the system and the analytical stability parameter. Regions of the hierarchically stable and unstable orbits in the phase space of the CSFBP are determined and their connection with the chaotic and regular regions of the phase space is explored.

22. *Renormalisation in uni-directionally coupled nonlinear dynamical systems*
Judi Thurlby
Affiliation:
Abstract. Consider the nonlinear dynamical system:

$$\begin{aligned} x_{n+1} &= 1 - \lambda x_n^2 \\ y_{n+1} &= 1 - Ay_n^2 - Bx_n^2. \end{aligned}$$

The first, independent component is the much studied quadratic family of maps which undergoes period-doubling to chaos as discovered by Mitchell Feigenbaum in he late 1970s. The unidirectionally coupled system is much less studied, and much more complex. One feature of such systems is the occurrence of so-called bicriticality in which the transition to chaos may be understood in terms of universal constants β (-1.505...) and δ_2 (2.392...), previously investigated by Kuznetsov et al. (1982), that occur alongside Feigenbaum's α and δ. We aim to give a rigorous computer assistede proof of the bicritical renormalisation operator:

$$R : (f_n, g_n) \to (f_{n+1}, g_{n+1}),$$

where

$$\begin{aligned} f_{n+1}(x) &= \alpha_n f_n(f_n(\alpha_n^{-1}x)) \\ g_{n+1}(x,y) &= \beta_n g_n(f_n(\alpha_n^{-1}x)), g_n(\alpha_n^{-1}x, \beta_n^{-1}y)) \end{aligned}$$

23. *Stagnant motion around periodic orbits in non-chaotic area-preserving map showing sub-diffusion and the properties of periodic orbit families*
Kensuke Yoshida, Shingo Watanabe, Akira Shudo
Affiliation:
Abstract. We investigate a non-chaotic area-preserving map defined on the cylinder that is called the Generalized Triangle Map (GTM). GTM generates sub-diffusion in the momentum direction, and the probability density function of momentum obeys the fractional diffusion equation that describes the sub-diffusion process generated by continuous-time random walk (CTRW) model. CTRW is a random walk model such that particles staying on a lattice point for a long time and jumping to a neighboring lattice point. In the weakly chaotic maps, such as the Pomeau-Manneville

map, CTRW describes the diffusion process by identifying marginal fixed points as lattice points of the CTRW model. We applied the same scenario to GTM, however, it has failed to describe the sub-diffusion in GTM. The peculiarity of the GTM is that all the periodic orbits form one-parameter families and densely distributed, which could lead to an unusual diffusion signature. In this poster, we discuss specific features of periodic orbits in the GTM and provide possible explanations for the observed anomalous diffusion.

24. *When does the chaos spoil the semiclassical approximation?*
Hajime Yoshino
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Abstract. We investigate the validity of the time-domain semiclassical approximation (SCA) for chaotic systems. It had been believed that SCA breaks down in the so-called Ehrenfest time (log h) due to stretching and folding dynamics of chaotic systems. However, in the early 90's, Tomsovic and Heller showed that SCA is valid far beyond the Ehrenfest time and their discovery was accepted with surprise. Although their result is of fundamental importance in the study of quantum chaos, the reason for such a long-time accuracy of SCA has not seriously been explored to date. Here, we tackle this issue by taking the Hénon map as a model system. Our idea comes from the fact that the topological nature of the Hénon map has closely been examined and well known compared to chaotic systems previously investigated. We found that, depending on the system parameter and the Planck constant, there exist several situations concerning the validity of SCA. We also consider a recently proposed scattering map, whose topological nature has been rigorously shown to be controllable, and report that an analogous argument as made for the Hénon map could be applied.

25. *Eigenvalues of random networks with cycles*
Pau Vimelis Aceituno
Affiliation: Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany
Abstract. The dynamics of complex networked systems are often studied using the eigenvalues of their adjacency matrix, a powerful mathematical tool with applications in telecommunications engineering, ecology, machine learning, neuroscience or social sciences. Since in real systems the exact graph structure is not known, researchers resort to random graphs to obtain eigenvalue properties from known structural features. However, this theory is not intuitive and only few results are known. In this note we offer a different perspective on this field by focusing on the cycles in a graph. We derive a relation between eigenvalues and cycle weights, and we use it to obtain spectral properties of random graphs with particular cyclic structures. We believe that the results presented here have broad implications: Cycles are easier to understand and quantify than eigenvalues, while eigenvalues are better suited to study a systems' stability and dynamics. By establishing a link between both, we give researchers interested in complex networks a way to combine the strengths of both approaches. Furthermore, we uncovered startling eigenvalue distributions for two families of random graphs, which, given their astonishing regularity, might be interesting for theoretical researchers working on random graphs and spectral theory.

26. *Propagation of frequency perturbations in heterogenous power grids*
Matthias Wolff, Pedro G. Lind, Philipp Maass
Affiliation: Fachbereich Physik, Universität Osnabrück, Germany
Abstract. To understand spreading of perturbations in power grids, simplified representations of grids have been investigated in the past (1,2). An important issue is to ascertain that the conclusions drawn from simplified models remain correct if grid heterogeneities are taken into account. In this scope, we analyze the spreading of the maximal frequency deflection at the nodes of a power grid after increasing the power at a single node during a short time interval. A synchronous machine approach is used to describe the power flow. The representation of the grid includes heterogeneities both in the grid nodes and in the transmission lines connecting them. We show that perturbations

do not necessarily propagate through shortest paths between nodes, but can have non-local effects. Furthermore, we observe that the propagation speed depends on the perturbed node and the modeling level of the grid.

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