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Talks

Complex network approach reveals global pattern of extreme-rainfall teleconnection

Jürgen Kurths

(Potsdam Institute for Climate Impact Research, Germany)

We analyse climate dynamics from a complex network approach. This leads to an inverse problem: Is there a backbone-like structure underlying the climate system? For this we propose a method to reconstruct and analyze a complex network from data generated by a spatio-temporal dynamical system. This approach enables us to uncover relations to global circulation patterns in oceans and atmosphere. We reveal the global coupling pattern of extreme-rainfall events by applying complex-network methodology to high resolution satellite data and introducing a technique that corrects for multiple-comparison bias in functional networks. We show that extreme-rainfall events in the monsoon systems of south-central Asia, east Asia and Africa are significantly synchronized. Moreover, we uncover concise links between southcentral Asia and the European and North American extratropics, as well as the Southern Hemisphere extratropics. Analysis of the atmospheric conditions that lead to these teleconnections confirms Rossby waves as the physical mechanism underlying these global teleconnection patterns and emphasizes their crucial role in dynamical tropical–extratropical couplings.

This concept is then applied to Monsoon data; in particular, we develop a general framework to predict extreme events by combining a non-linear synchronization technique with complex networks. This way we analyze the Indian Summer Monsoon (ISM) and identify two regions of high importance. By estimating an underlying critical point, this leads to a substantially improved prediction of the onset of the ISM.

We emphasize that this reconstruction approach can be also applied to neuroscience, genomics and engineering.

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Pattern formation in populations with density-dependent movement and two interaction scales

Ricardo Martinez Garcia

(Princeton University)

In this presentation, I will discuss a model of interacting particles in which the mobility individual movement is determined by the population crowding at two different spatial scales. This picture mimics the behavior of some biological organisms that tend to cluster at short ranges as a defensive strategy, but strongly disperse if there is a high population pressure at large ranges in order to optimize foraging. Combining stochastic simulations of the particle-level dynamics and analytical inspections of its continuous description (a nonlinear diffusion equation), I will show how scale-dependent behaviors may give rise to a rich formation of spatial patterns, including a periodic arrangement of ring-like structures.

Shearless Invariants in Non twist Symplectic Maps

Iberê Luiz Caldas

(Institute of Physics, University of São Paulo)

Nontwist Hamiltonian systems have shearless invariant curves that act like barriers in phase space [1, 2]. Recently, secondary shearless curves have also been identified in the phase space of twist maps, in the neighbourhood of peculiar bifurcations of elliptic fixed points [3]. We use Slater's theorem to develop a qualitative and quantitative numerical approach to determine the breakup of invariant curves in the phase space of area-preserving maps [4]. We also determine the breakup critical parameters, of the shearless curves, with a procedure based on the determinism analysis performed on the recurrence plot of orbits near the critical transition [5].

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Microtransitions in hierarchical and Climate networks

Gupte Neelima Madhukar

(Indian Institute of Technology Madras)

The prediction of the critical point of a phase transition is a topic of great current interest, and is of utility in many practical contexts. Therefore, the identification of precursors, or early warning signals of the critical point, has become the focus of current interest. Recent model studies have shown that a series of small transitions, which have been called microtransitions, act as precursors to the percolation transition. Here, we identify the existence of microtransitions in two distinct networks, for two distinct processes. The first case is the process of avalanche transmission on branching hierarchical networks. Here, typical realizations of the original lattice of this network exhibit a second order transition. We note that microtransitions in the variance of the order parameter are seen in this case. Additionally, the positions of the microtransitions follow a scaling relation. The scaling relation can be used to calculate the position of the critical point, which is seen to be in agreement with the observed result. We also introduce this method of identifying the microtransitions occurring before the tipping point to a complex real world system, the climate system. We analyze the discontinuous first order phase transition occurring in the climate networks. We apply the percolation framework to these networks to analyze the structural changes in the network and construct an order parameter and a susceptibility. Microtransitions can be found in the behaviour of the susceptibility. These can be used to predict the tipping point in the system. We discuss possible applications of this, and other predictors to the prediction of the El Nino phenomenon, and cyclonic activity in the Indian Ocean region.

Emergent Hyperbolic Network Geometry and Frustrated Synchronization

Ginestra Bianconi

(Queen Mary University of London)

Topology has been recently shown to be key to study neuronal dynamics and brain function. In this context experiments probing the dynamics of networks of neuronal cultures have revealed that this dynamics is strongly dependent on the network topology and in particular on the network dimensionality. However, this phenomenon has been so far mostly unexplored from the theoretical point of view. Here we reveal the rich interplay between network topology, emergent network geometry and synchronization of coupled oscillators in the context of a simplicial complex model of manifolds called Complex Network Manifold. The networks generated by this model combine small world properties (infinite Hausdorff dimension) and a high modular structure with finite and tunable spectral dimension. We show that the networks display frustrated synchronization for a wide range of the coupling strength of the oscillators, and that the synchronization properties are directly affected by the spectral dimension of the network.

Computational Hardness as Chaos in an Analog Approach to Boolean Satisfiability Problems

Zoltán Toroczkai

(University of Notre Dame)

Many real-life problems can be formulated in Boolean logic as a class of problems where the task is finding Boolean assignments to variables satisfying the maximum number of logical constraints. When all the constraints are satisfiable, they are called SAT problems and belong to the NP-complete class, whereas the others are called MaxSAT and they are NP-hard. For this reason, no discrete algorithm is known to efficiently solve these problems. Here we present a continuous-time analog solver for SAT and MaxSAT and show that in the latter case, the scaling of the escape rate, an invariant of the solver's dynamics, can predict the maximum number of satisfiable constraints, often well before finding the optimal assignment. We demonstrate that problem hardness is translates into chaotic behavior in the dynamical system. We show that analog solution times scale polynomially with problem size, although at the expense of exponential fluctuations in the solver's energy function. Simulating the solver, we illustrate its performance on MaxSAT competition problems, and apply to Ramsey number problems. This approach highlights the potential of continuous dynamical systems as algorithms for discrete optimization. We end with a discussion of computational complexity in the continuous-time analog domain.

Mathematical model of brain tumour

Kelly Cristiane Iarosz

(Institute of Physics (University of Sao Paulo))

In recent years, it became clear that a better understanding of the interactions among the main elements involved in the cancer network is necessary for the treatment of cancer and the suppression of cancer growth. In this work we propose a system of coupled differential equations that model brain tumour under treatment by chemotherapy, which considers interactions among the glial cells, the glioma, the neurons, and the chemotherapeutic agents. We study the conditions for the glioma growth to be eliminated, and identify values of the parameters for which the inhibition of the glioma growth is obtained with a minimal loss of healthy cells.

Firing patterns in networks of adaptive exponential integrate-and-fire neuron model

Fernando da Silva Borges

(UFABC, Brazil)

We have studied firing patterns in networks of adaptive exponential integrate-and-fire neurons connected by chemical synapses. We show how spiking or bursting synchronous behaviour appears as a function of the coupling strength and architecture of networks, by constructing parameter spaces that identify these synchronous behaviours from measurements of the inter-spike interval and the calculation of the order parameter. Moreover, we verify the robustness of synchronisation by applying an external perturbation to each neuron. The simulations show that bursting synchronisation is more robust than spike synchronisation.

Properties of Liquid water from atomistic simulations and neural networks

Alexandre Reily Rocha

(Instituto de Física Teórica - UNESP)

Stochastically driven hubs induce coherence resonance and synchronisation

Tiago Pereira

(ICMC-USP São Carlos)

Disparate real-world networked systems share an important structural feature: they have a few highly connected nodes called hubs. We study noise driven self-sustained oscillations coupled through a network with hubs. We show that stochastic effects synergize with the heterogeneous structure to create nonlinear phenomena such as noise-induced synchronization and coherence resonance. That is, collective transitions would not be possible by the sole presence of noise and sole network structure. This reveals that nonlinear interaction between network structure and stochastic effects play a fundamental role in complex systems.

Transient chaos in networked systems: Desynchronization and real-time vulnerability

Ulrike Feudel

(Oldenburg University, Germany)

Authors: Everton S. Medeiros, Rene O. Medrano, Iberê L. Caldas, Tamas Tél and Ulrike Feudel

We analyze the final state sensitivity of nonlocal networks of Duffing oscillators with respect to the initial conditions of their units. By changing the initial conditions of a single network unit, we perturb an initially synchronized state, which is the only attractor for a single unit. Depending on the perturbation strength, we observe the existence of two possible network long-term states: (i) The network neutralizes the perturbation effects and returns to its synchronized configuration. (ii) The perturbation leads the network to an alternative desynchronized state. By computing uncertainty exponents of a two-dimensional cross section of the state space, we find the existence of a fractal set of initial conditions converging to this desynchronized solution, which appears to be either a new attractor or a chaotic saddle, i.e. an unstable chaotic set on which trajectories persist for extremely long times. Furthermore, we report the existence of an intricate time dependence of the vulnerability of the synchronized states in a network composed of identical electronic circuits. By perturbing the synchronized dynamics in consecutive instants of time, we find that synchronization breaks down for some time instants while it persists for others. The mechanism behind this intriguing phenomenon is again the existence of an unstable chaotic set close to the synchronized trajectory. Both phenomena highlight the crucial role played by unstable chaotic set leading to transient chaotic dynamics in networked systems. We discuss that these phenomena are generic for large classes of nonlinear dynamical systems.

Symmetric States Requiring System Asymmetry: The Emergent Role of Heterogeneity in Network Dynamics

Adilson E. Motter

(Northwestern University)

Symmetry breaking--the phenomenon in which the symmetry of a system is not inherited by its stable states--underlies pattern formation, superconductivity, and numerous other effects. In this talk, I will report on the recently established possibility of the converse of symmetry breaking, an emergent phenomenon in which a stable state is symmetric only when the system itself is not. In particular, I will present an experimental demonstration of this phenomenon as well as concrete applications to network optimization and control. The presentation will also discuss how the converse of symmetry breaking challenges the fundamental and widely held assumption that identical agents are necessarily more likely to exhibit similar behavior. I will show that it can, in fact, give rise to beneficial effects of heterogeneity in numerous complex systems in which interacting entities are required to exhibit coordinated behavior. Through this presentation, I hope to convey that our research in network dynamics is now not only benefiting from statistical and nonlinear physics, but also fostering foundational discoveries in these areas.

Scientific challenges in regional and global climate change

Paulo Artaxo

(Universidade de São Paulo)

The non linear and chaotic behavior of the climate and its relationship with human activities is a scientific challenge that needs a coherent and global effort. Our plane is warming much faster that predicted by the models, emissions are increasing fast and impacts are already observed in all continents. With the current CO2 emissions, that are still growing at 2.4% a year, it is now impossible to achieve an average 2 degrees warming. There will be large impacts on climate extremes, changes in precipitation and changes in ecosystem functioning as well as on biodiversity. We will make a review of recent IPCC, IPBES, WHO, WMO reports and recent literature discussing the complex issue of climate change and to what new Earth state we will be heading to.

Forecasting monsoon: insight from Nonlinear dynamics

Elena Surovyatkina

(Potsdam Institute for Climate Impact Research (PIK))

Much of the world's population depends on monsoon rainfall. Although the rainy season happens annually, the time of monsoon season's onset and withdrawal varies within a month from year to year. Seasonal variability implies two aspects: first, the seasons do not begin at fixed dates but have to be determined by observation and are known only after the fact; and second, a new season begins at different dates in different parts of the country and over the world. Seasonal variability strongly affects different aspects of human life such as agricultural productivity and food security and economic growth.

Numerical Weather Prediction has a limit to forecast the weather for up to approximately 10 days in the future. Hence, the seasonal prediction is a considerable scientific challenge with great importance for society. In our study of the Indian monsoon season, we have found the evidence in observational data that we can consider the onset of monsoon as a critical transition from pre-monsoon to monsoon. We use the phenomenon of critical growth of fluctuations [2] to detect Tipping elements of monsoon. This finding allows us to develop the Tipping elements approach for prediction of onset and withdrawal dates of Indian summer monsoon [1]. Our prediction relies on observations of near-surface air temperature, and relative humidity from both the ERA-40 and NCEP/NCAR reanalyzes. Our results show that our method allows predicting the monsoon as retrospectively (over the period 1951-2015), as well in the future. In 2016, 2017, 2018 we successfully predicted the onset and withdrawal dates of the Southwest monsoon over the central part of India for 40 and 70 days in advance respectively [3]. Hence, we proved that such early prediction of season timing is possible. The Tipping Element Approach is a crucial step forward for forecasting monsoon that is of high social impact and significant contribution in atmospheric sciences. It is opening up new areas for inquiry, future research for frontier areas such as hydrology, agriculture, tropical meteorology.

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Non-intermittent Turbulence: Lagrangian Chaos and Irreversibility

Samriddhi Sankar Ray

(International Center for Theoretical Sciences, Tata Institute of Fundamental Research)

Turbulent flows are special examples of extended dynamical systems distinguished by their intermittent, chaotic, and irreversible behavior. However, the exact nature of the effect of intermittency on the chaotic nature of turbulence, and vice versa, is still not known. By using a recent discovery [U. Frisch, A. Pomyalov, I. Procaccia, and S. S. Ray, Phys. Rev. Lett. 108, 074501 (2012)] of Fourier decimation, we manipulate the nonlinearity to try and isolate the origins of intermittency, chaos, and irreversibility in homogeneous, isotropic turbulence. In particular, we show that within the Lagrangian framework it is possible to have nonintermittent, yet chaotic, turbulent flows, with an emergent time reversibility as the effective degrees of freedom are reduced through decimation. These results suggest a new microscopic way, starting from the equations of motion, of understanding turbulence beyond what is possible through phenomenological models.

Bifurcation analysis and control of chaos on bistable piezoelectric energy harvesting systems

Americo Barbosa da Cunha Junior

(Rio de Janeiro State University)

The technological breakthroughs of the last decade have given rise to a series of mobile devices (e.g. cell phones, medical implants, micro-sensors, etc.) which the proper functioning demands autonomous sources of energy. In this context, the vibration energy harvesters, based on piezoelectric effect, present themselves as a very appealing solution, since, when operating in a nonlinear regime, they are able to recover considerable amounts of energy in a wide band of frequencies outside a resonance. In order to better understand the efficiency of the electromechanical energy conversion processes on these systems, the present work conducts a detailed study of the bifurcations of a typical bistable energy harvester, which is characterized by a Duffing oscillator driven by a harmonic excitation. Different frequency bands and amplitude of excitation are considered in the analysis, showing that this type of harvester has an extremely rich dynamics, with the presence of several mechanisms of bifurcation, hysteresis and chaos. In order to explore possible chaotic regimes in favor of the energy recovering process, the application of classical techniques of chaos control (OGY and Pyragas), to stabilize the system in unstable periodic orbits associated with high levels of energy, is also presented. The results show that the exploitation of the chaotic regime can be very useful in improving the efficiency of the system.

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Model for laws of scale in urban systems

Camilo Rodrigues Neto

(EACH - University of Sao paulo)

When humanity built the first cities, it brought together previously separated individuals, increasing social and economic interactions. In cities, shared use of infrastructure has allowed these interactions to be more constant and efficient, producing economies of spatial scale as they grow and at the same time gain gains in their socioeconomic productivity. The socio-economic variables of a city grow faster than a linear relationship with the population, in a log-log graph, the so-called superlinear scaling. On the other hand, the larger the city, the more efficient is the use of its infrastructure, leading to a sublinear escalation for these variables. We present a microscopic model, based on the interactions of the inhabitants of the cities, which presents the laws of superlinear and sublinear scale, respectively, for the socioeconomic and infrastructure variables observed empirically.

Inequality in Random Markets

Ricardo Lopez-Ruiz

(University of Zaragoza, Spain)

Some economic gas-like models for random conservative markets are addressed in this communication. In these models the agents trade by pairs bringing the system toward an statistical equilibrium, this is the asymptotic wealth distribution. The time evolution of these models are given by nonlinear functional mappings. These maps are nonlinear operators in the space of wealth distributions, which are shown to conserve the total and mean wealth of the economic system, and even an H-Theorem can be verified for some cases. Different asymptotic results for several models are presented. The decay to the exponential distribution is found in some of them and a transition to power-like distributions is sketched when a naive bank system is suggested. Simulations and implementations of these systems in different topologies are also presented. In all these models, inequality is a natural consequence of randomness without the need of some special force or intervention from the exterior. Even more, different types of randomness give place to different kinds of natural inequality.

Suppression of Synchronization due to Delayed Feedback Signals in Neural Networks

Fabiano Ferrari

(Universidade Federal dos Vales do Jequitinhonha e Mucuri, Brazil)

Synchronization of neurons can be achieved by increasing neural coupling strength or applying a common external signal in the neural network. The unsynchronized state of neurons can be recovered through external perturbation, however, this is not trivial and depend on the properties of the system. In this talk, we are going to present results about suppression of synchronization using delayed feedback signals.

Chaos synchronization based on linear and adaptive controls: theory and experiment

Egunjobi Abiodun Isiaka

(Federal University of Agriculture Abeokuta, Nigeria)

This investigate the synchronization of nonlinear chaotic systems based on single variable linear feedback and adaptive controller. Theoretical approaches to control design, based on Lyapunov stability.

Fractal structures in open Hamiltonian systems: examples in Plasma Physics

Ricardo Luiz Viana

(Universidade Federal do Paraná)

Fractal structures are very common in nonlinear dynamical systems, and their study provides valuable insights on questions related to the nonuniformity of their observed behavior. In open Hamiltonian systems it is often the case that the boundaries between escape basins are fractal. It is possible to characterize the fractal structures by computing the uncertainty exponent, the basin entropy and basin boundary entropies, as well as the so-called Wada property, when there are three or more escape basins. We investigate the fractal nature of such structures in problems of interest in plasma physics, related to the ExB motion of charged particles under electrostatic waves and magnetic field line behavior in fusion plasmas with chaotic limiters.

Low dimensional dynamics and invariant manifolds in stratified turbulence

Pablo Mininni

(Universidad de Buenos Aires)

Turbulent flows are characterized by a huge number of degrees of freedom, and display erratic behavior with extreme events and non-Gaussian statistics. However, under some conditions their dynamics can be captured by reduced systems with a few degrees of freedom. In this talk I will present some dimensional reductions that can be applied to stably stratified turbulence, a case of interest for atmospheric and oceanic flows. Such flows display strong and spatially localized vertical drafts, anisotropic mixing, and non-stationary large fluctuations in the velocity and the temperature, as well as in their gradients. Starting from the partial differential equations that describe the flow dynamics I will consider two simple models that capture the competition between gravity waves on a fast time-scale, and non-linear steepening on a slower time-scale. One model, derived from empirical arguments, points to the existence in these flows of a resonant regime characterized by enhanced large-scale intermittency and linked to the emergence of specific structures in the velocity and temperature. A second model, derived more rigorously from the exact equations for the evolution of velocity and temperature gradients, indicates the system has a few invariant manifolds over which the dynamics of fluid elements becomes significantly slower. These manifolds are associated to regions of local stability and of local convection in the flow.

Network-based tools for retina image classification and outlier detection

Cristina Masoller

(Universitat Politecnica de Catalunya)

Nowadays, unprecedented advances in machine learning for biomedicine have led to a variety of unsupervised methods for remote image analysis, allowing for cost-effective early detection of diseases. Here I will present several methods for retina image analysis, which we have recently developed, aimed at exploiting nonlinear analysis tools and network theory. First, I will discuss an unsupervised algorithm for the analysis of optical coherence tomography (OCT) anterior chamber images, which extracts features that discriminate between healthy subjects and patients with angle-closure [1]. Then, I will present analysis tools for retinal fundus images that extract features that allow to discriminate between healthy subjects and those with glaucoma or diabetic retinopathy [2, 3]. Finally, I will discuss how the percolation transition in networks can be exploited for outlier mining in different types of datasets including anterior chamber OCT images [4].

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Individual and collective bacterial motions

Bruno Eckhardt

(Phillipps-Universität Marburg)

Bacteria provide one of the earliest examples of active matter and are a constant source of surprising observations. Bacteria have molecular motors in their membranes that rotate long long filaments, flagella, to move in fluids. It was known that bacteria use the reversal of their motor to move backwards and/or to reorient their direction of motion, switching between a run and a tumble phase, or by initiating a reverse-and-flick process. In obstructed environments, it was recently found that they can exploit a mechanical instability of the flagellum to warp the flagellum around cell body so as to be able to escape in a screw-like motion [1]. This process seems to be so important for the bacteria that they also adjust the molecular composition of the flagellum in a manner that assists this process [2]. In their swarming phase, larger communities of bacteria show a variety of phases that differ, among other parameters, in the fraction of motile and non-motile components, directional correlations, and swimming speed. Using Machine Learning tools, it has been possible to distinguish five different phases [3]. Finally, denser suspensions of bacteria give rise to vortices and jets, reminiscent of turbulent flow fields. In a theoretical study we have analyzed the conditions that have to be reached in order to trigger the onset of the inverse cascade in two-dimensional turbulence, leading to the formation of large scale patterns that dominate the flow [4,5].

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Targeting the dynamics of ecological networks

Ricardo Gutiérrez

(Universidad Rey Juan Carlos)

The targeting procedure shows how to steer the dynamics of a network of oscillators (whose global initial condition cannot be arbitrarily modified) towards a particular trajectory fully compatible with its equations of motion [1].The method is based on coupling the nodes of the network to those of an identical network that evolves according to the dynamics that is to be imposed on the original system, and yields a ranking of nodes indicative of their relevance for achieving or maintaining a dynamical regime. In practice, the copy of the original network does not need to exist physically, but can be an experimental recording of the desired evolution of the original physical network Recently, many of the topological and dynamical assumptions of the original formulation have been shown to be unnecessarily restrictive. The generalized method has been successfully applied to the study of ecological networks, where it yields a ranking of species that need to be controlled in order to achieve a desired evolution, thus providing relevant information for environmental management [2].

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Transport barrieres with shearless atractors

Ricardo Egydio de Carvalho

(Institute of Geosciences and Exact Sceinces - UNESP-RC)

We present a mechanism to generate a sequence of shearless curves or attractors to form a band of transport barriers. We consider the labyrinthic non-twist standard map to prepare a scenario with three shearless curves. Dissipation is introduced and three shearless attractors coexist, very close each other. In both cases a collective transport barrier is formed.

Exploiting the spatial signatures of causality to understand social crisis in Brazil

Murilo Baptista

(Institute of Complex Systems and Mathematical Biology, University of Aberdeen)

Authors: Norma Valencio, Arthur Valencio and Murilo S. Baptista

Brazilian municipalities have faced multifaceted crises resulting in the deterioration of the relationship between local public administration and citizens. One of these crises emerges as a result of disasters, characterized not only by the collective stress associated with multiple damages, but also by the controversial institutional practices for managing them. Although the dissemination and recurrent declaration of state of emergence across the country suggest disasters are out of control, these decrees may also indicate that a new kind of policy practice is being established, which in place quite regularly these exceptional legal and operational artefacts for events with a dubious genuine disaster character. The issues involved are more immediately related to the gradual split between the factual events and the bureaucratic modus operandi of the local administration leading to risks of loss of public credibility in civil protection policies. Considering this problem, our purpose is to present the spatiotemporal dynamics of these systemic crises in the Brazilian municipalities in the last years (2003-2018) as well as to test possible correlations and causal relations with other socioeconomic variables. We have developed the Multithread Causality Toolbox, which was applied to evaluate the existence and strength of causal links by calculating the Transfer Entropy and Causal Mutual Information (CaMI). This open source toolbox explores the spatial signatures of causality which allows for its assessment in complex data sets. The results indicate that variables related to social inequalities are more relevant to explain this kind of ambiguity: a public administration practice originally designed to tackle exceptional circumstances being operated routinely.

Soliton crystals in ring-shaped optical microresonators: reconstruction scenario and stability

Alain Dikande

(University of Buea)

Soliton crystals are periodic patterns of multispot high-intensity optical fields that form from time or space entanglements of equally separated identical pulses. These specific nonlinear optical structures have gained interest in recent years with progress in nonlinear optics and particularly, the advent of optical ring microresonator devices. In this talk we shall explore characteristic features of soliton crystals, with an emphasis on their one-to-one correspondence with elliptic solitons. With this purpose in mind we examine their formation, their stability, and their dynamics in ring-shaped nonlinear optical media within the framework of the Lugiato-Lefever equation. The stability analysis deals with internal modes of the system, via a 2×2-matrix Lamé-type eigenvalue problem the spectrum of which will be shown to possess a rich set of bound states, consisting of stable zero-frequency modes and unstable decaying as well as growing modes. By means of the collective-coordinate approach, and direct numerical simulations of the Lugiato-Lefever equation, the soliton-crystal dynamics in optical ring fibers will be analyzed.

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Connecting Networks

Javier M. Buldú

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The emergence of cooperation, defection or altruism can be investigated by linking game theory to network science. While attention was initially focused on the interplay between nodes' strategies and the structure of the underlying (single) network, more recently, coevolutionary rules have also been related to the emergence of interdependency and multilayer structures. But, what if we are concerned about the interests of a network as a whole instead of its nodes? Does it make sense to consider networks competing or collaborating with other networks? The recent literature about networks-of-networks, or in a more general context about multilayer networks, makes these two questions timely and extremely relevant. Here we will show how networks compete or cooperate to achieve a relative increase of importance measured as eigenvector centrality, which maximizes their outcome in a variety of dynamical processes. In our competition, networks can vary the way they interact with other networks, evolving in time until they reach a stable situation where all networks refuse to modify their strategy because any change would lead to a worse result. Importantly, an a priori optimal connection strategy for a given network may not be reachable due to the actions of the competitor networks, which turns the analysis of the final outcome of the networks into a study of Nash equilibria in a network-of-networks.

Quantifying echo chamber effects in information spreading over political communication networks

Silvio C. Ferreira Júnior

(Universidade Federal de Viçosa, Brazil)

Echo chambers in online social networks, in which users prefer to interact only with ideologically-aligned peers, are believed to facilitate misinformation spreading and contribute to radicalize political discourse. In this paper, we gauge the effects of echo chambers in information spreading phenomena over political communication networks. Mining 12 millions of Twitter messages, we reconstruct a network in which users interchange opinions related to the impeachment of the former Brazilian President Dilma Rousseff. We define a continuous polarization parameter that allows to quantify the presence of echo chambers, reflected in two communities of similar sizes with opposite views of the impeachment process. By means of simple spreading models, we show that the capability of users in propagating the content they produce, measured by the associated spreadability, strongly depends on their polarization. Users expressing pro-impeachment sentiments are capable to transmit information, on average, to a larger audience than users expressing anti-impeachment sentiments. Furthermore, the users' spreadability is strictly correlated to the diversity, in terms of political polarization, of the audience reached. Our findings demonstrate that political polarization can hinder the diffusion of information over online social media, and shed light upon the mechanisms allowing to break echo chambers.

Entropic Dynamics on Statistical Manifolds

Pedro Pessoa

(University at Albany/ State University of New York, USA)

Since Boltzmann and Gibbs, canonical distributions have been fundamental in statistical physics. In a modern approach [Jaynes: Phys. Rev. 106, 620, 1957] they appear naturally as a solution to a well set optimization problem: maximizing entropy under a set of expected values constraints. Generally in physics such expected values define the macrostates, and the space in which the canonical distribution is defined are the microstates. It happens so that the space of possible macrostates can be regarded as a space of parameters for canonical distributions (statistical manifold). In the field of Information Geometry [Amari and Nagaoka: Methods of Information Geometry, American Mathematical Soc. , 2007] these distributions happen to have deeply interesting geometrical properties such as their metric tensor is a covariance matrix and important thermodynamical objects, such as free energy, appear naturally. The use of information geometry in statistical physics is not new [Ruppeiner: Rev. Mod. Phys. 68, 313, 1996][Brody: Phys. Rev. E 51, 1006, 1995]. But in this work we want to provide a systematic way to create dynamical systems in the space of such probability distributions. This can give new insight on fields such as critical phenomena and renormalization groups as well as deal with statistical problems in which the microstate dynamics is not so well defined (such as economics and ecology). These dynamics are derived as an application of entropic methods of inference i.e. that is a form of entropic dynamics [Caticha: Entropy 17, 6110, 2015]. The flows of probability distributions is driven by entropy subject to constraints. As an example we show how entropic dynamics is applied to well-known thermodynamical models with phase transition, such as the Van der Walls gas.

Phase synchronization and intermittent behavior in healthy and Alzheimer affected human brain based neural network

Roberto Cesar Budzinski Neto

(UFPR, Brazil)

The study of dynamical properties regarding phase synchronization and intermittent behavior of neural systems is possible by using a network of networks structure based on an experimentally obtained human connectome for healthy and Alzheimer-affected brains. Here, it is considered a network composed of 78 neural subareas (subnetworks) coupled with a mean-field potential scheme. Each subnetwork is characterized by a small-world topology composed of 250 bursting neurons simulated through a Rulkov model. Using the Kuramoto order parameter it is possible to demonstrate that healthy and Alzheimer-affected brains display distinct phase synchronization and intermittence properties as a function of internal and external coupling strengths. In general, for the healthy case, each subnetwork develops a substantial level of internal synchronization before a global stable phase-synchronization state has been established. For the unhealthy case, despite the similar internal subnetwork synchronization levels, higher levels of global phase synchronization occurring even for relatively small internal and external coupling are observed. Using recurrence quantification analysis, namely the determinism of the mean-field potential, regions where the healthy and unhealthy networks depict nonstationary behavior are observed, but the results denounce the presence of a larger region or intermittent dynamics for the case of Alzheimer-affected networks. The results make possible a theoretical explanation based on the existence of two locally stable but globally unstable states.

Self-organization and Nonuniversal Anomalous Scaling in Non-Newtonian Turbulence

José Soares de Andrade Jr.

(Departamento de Física - Universidade Federal do Ceará)

In many situations ranging from blood flow to atomization of slurries in industrial processing, one encounters non-Newtonian fluids in turbulent conditions. Intuitively, in the inertial subrange, molecular stresses should have a negligible influence on the motion and size of the eddies, regardless of the rheological nature of the fluid. More precisely, even if a more complex constitutive law than a linear one is necessary to describe the stress-strain relation of a moving fluid, one should expect the statistical results obtained for the structure of Newtonian turbulence at the inertial subrange to remain valid. A relevant question that naturally arises is how the local rheological properties of the fluid must rearrange in space and time to comply with this alleged structural invariance. Here we investigate through Direct Numerical Simulations (DNS) the statistical properties of turbulent flows in the inertial subrange for non-Newtonian power-law fluids. Our results show that the structural invariance found for the vortex size distribution is achieved through a self-organized mechanism at the microscopic scale of the turbulent motion that adjusts, according to the rheological properties of the fluid, the ratio between the viscous dissipations inside and outside the vortices. Moreover, the deviations from the K41 theory of the structure functions' exponents reveal that the anomalous scaling exhibits a systematic nonuniversal behavior with respect to the rheological properties of the fluids.

What topological factors affect network inference?

Nicolás Rubido

(Universidad de la República, Instituto de Física de Facultad de Ciencias)

A main goal in the analysis of a complex system is to infer its underlying network structure from time-series observations of its behaviour. The inference process is often done by using bi-variate similarity measures, such as the cross-correlation (CC), however, the main factors favouring or hindering its success are still puzzling. Here, we use synthetic neuron models in order to reveal the main topological properties that frustrate or facilitate inferring the underlying network from CC measurements. Specifically, we use pulse-coupled Izhikevich neurons connected as in the Caenorhabditis Elegans neural networks as well as in networks with similar randomness and small-worldness. We analyse the effectiveness and robustness of the inference process under different observations and collective dynamics, contrasting the results obtained from using membrane potentials and inter-spike interval time-series. We find that overall, small-worldness favours network inference and degree heterogeneity hinders it. In particular, success rates in C. Elegans networks -- that combine small-world properties with degree heterogeneity -- are closer to success rates in Erdös-Rényi network models rather than those in Watts-Strogatz network models. These results are relevant to understand better the relationship between topological properties and function in different neural networks.

Ordering and ranking of complex high-dimensional data

Mario Chavez

(Hôpital de La Pitié-Salpêtrière)

In the case of univariate data, many nonparametric methods use ranks of the data. Nevertheless, the concept of order or rank in high dimensional data is not well defined. Here, I propose a graph-based ranking procedure that can be applied to multivariate time series, network's nodes, or any manifold-valued data endowed with a distance. I illustrate the method by characterizing the complexity of multivariate chaotic systems, and by ordering the nodes in a complex network in terms of the most and least central. I also discuss other potential applications.

Structure and dynamics of networks: a machine learning approach

Francisco Aparecido Rodrigues

(Institute of Mathematics and Computer Science, University of São Paulo)

Although the prediction of dynamical processes from network structure is one of the most important challenges in network science, the problem is very difficult due to the linearities in the dynamic models, correlations due to the connected nodes and feedbacks resulting from the interactions. However, we will show that this prediction can be performed by machine learning algorithms. The outbreak size starting from a single node and the state of Kuramoto oscillators is predicted following our approach. Moreover, our method can quantify the importance of network measures on the evolution of the dynamical process. In the case of epidemic spreading, we show that this method can be used to identify the most influential spreaders in networks with higher accuracy than previous methods. Our approach is very general and can be applied to predict any dynamical process running on the top of complex networks.

Estimation of dengue's burden in Venezuela using neighboring and internet-source data.

José L. H. Diestra

(IFT-UNESP/ICTP-SAIFR)

Humanitarian crises, such as those unfolding in Venezuela due to amid civil unrest, often elevate the risk of and are exacerbated by infectious disease outbreaks. Rapid and efficient responses are paramount in such emergencies. To address this challenge, we develop multivariate early warning and situational awareness surveillance systems for arboviruses. Colombia and Venezuela, with populations over 48 and 31 million, respectively, share a vast border with more than 30,000 crossings daily. Given their proximity, border fluidity, and similar environmental characteristics (weather, altitude, etc), we hypothesize that Colombian infectious disease data might provide situational awareness for Venezuela at a time when political unrest is undermining public health. We use weekly dengue reports for every state in Venezuela and Colombia back to 2001, with which we initially fit a dengue model to determine spatiotemporal patterns, as well as possible environmental and geopolitical predictors. We then apply our surveillance optimization methods to identify combinations of state-level Colombian surveillance data, dengue-related Spanish Google Trends data (at the state and national scale), and other internet-source and environmental data that yield robust, real-time indications of dengue emergence and prevalence in individual states of Venezuela and nationwide.

Evolution and Dynamics of World Currency Network

Nivedita Deo

(University of Delhi)

We study the statistical and spectral properties of the foreign exchange of 21 different currencies from January 4, 1999 to March 30, 2018. The FX rates are expressed in term of a base currency (United States Dollar (USD)) which serve as the frame of reference for all other currencies. The dynamics and evolution of the all other currencies are studied in the frame in which the base currency is at rest. The correlation matrix is calculated for different periods with a rolling window method and the properties are studied for each window. The basic statistics on the correlation matrix shows that the currencies are more and more correlated with times. The distribution of the correlation matrix was very asymmetric with non zero skewness which shows a fat tail behavior for the initial years but approach Gaussian distribution for the later time. The spectral properties of the correlation matrices for each window when compare with the properties of the correlation matrix formed for the complete period and with analytical results for Wishart matrices shows that the distribution is different for the windows comprising the calm and the crisis period. The study of the number of eigenvalues which are outside the random matrix bounds for each window on both sides of spectrum reveals that for the crisis period, the number of eigenvalues outside the lower bound increases as compared to the calm period. This increase in the number of eigenvalues on the lower side of the spectrum for a window also implies a crisis in the near future. The lower end of the spectra contains more information than the higher side as revealed by the entropic measures on the eigenvalues. This entropic measure shows that the eigenvectors on the lower side are more informative and localized. In this work, the analysis of individual eigenvector captures the evolution of interaction among different currencies with time. The analysis shows that the set of most interacting currencies that are active during the calm period and the crisis period are different. The currencies which was dominating in the calm period suddenly lose all weight and new set of currencies become active at the onset and during the crisis. The largest eigenvector of the correlation matrix can separate currencies based on their geographical location. The network analysis uses the Fruchterman-Reingold layout to find clusters in the network of indices at different thresholds.

Non-chaotic classical transitions

Emanuel Fernandes de Lima

(UFSCar, Brazil)

We consider the classical dynamics of one-dimensional systems driven by time-dependent fields. In the presence of the external fields, some invariant tori are destroyed giving rise to chaotic layers, while some tori, though distorted, remain. Each surviving torus covers a certain range of the energy of the initial unperturbed system. Based on this observation, we show that using appropriately designed time-dependent pulses, it is possible to perform transitions between distinct energies through non-chaotic routes. In particular, if there are distorted tori that cross a separatrix of motion of the unperturbed system, the non-chaotic transitions between two different regimes of motion can be induced by a tailored pulses. We apply this scheme to the control of photodissociation and photoassociation in the driven Morse oscillator.

Protocol for suppression of phase synchronization in Hodgkin-Huxley-type networks

Bruno R. R. Boaretto

(UFPR, Brazil)

Phase synchronization of neurons is fundamental for the functioning of the human brain which can be related to neurological diseases such as Parkinson and/or seizure behaviors generated by epilepsy. For small-world networks, an atypically high level of phase synchronization may occur even for unexpected low values of the coupling strength when compared to traditional critical values which delimit the transition from a globally stable unsynchronized to a globally stable phase synchronized states. This regime is characterized by a non-monotonic transition as a function of the coupling parameter. In order to study this phenomenon, we consider a neural network composed of 5,000 Hodgkin-Huxley-type neurons, coupled by a small-world connection matrix. Based on suppression protocols of phase synchronization, we study how this abnormal phase synchronization can be suppressed by applying an external pulsed current in the network. It is shown that the synchronization for weak coupling can be suppressed without any visible effect in the globally stable asymptotic state occurring for higher values of the coupling strength. We also demonstrate that to preserve the unsynchronized state, the external current must be kept switched on, otherwise, the abnormal synchronization regime is recovered due to the globally stable state present on the dynamics. Optimization protocols are studied by varying the amplitude and time intervals of the current pulses.

Effects of neural variability on the phase synchronization of neural networks

Kalel L. Rossi

(UFPR, Brazil)

The inter-burst (or inter-spike) interval variability, measured by the standard deviation of the time between bursts (or spikes), is an important neuronal property whose effects on information coding on the brain are widely studied. In the present work, we are interested in the effect the variability has on the phase synchronization of neural networks, which is itself also associated with relevant phenomena, such as memory and information binding. We calculate the inter-burst interval variability of modified Hodgkin-Huxley neurons, coupled through an Erdos-Renyi connection scheme, and show that it correlates with the degree of phase synchronization of the network, as measured by the Kuramoto order parameter. We then calculate the number of neurons that are clustered together, as well as the time each neuron stays in the cluster. We find that the variability is inversely proportional to the size and stability of the cluster. If the variability is sufficiently high, neurons stay together only for a few bursts, despite the network as a whole being highly synchronized. The results thus show that the variability has a strong influence in both the degree of synchronization and the stability of inter-neuron synchronization.

Robust chaos induced by two-frequency excitation

André Gusso

(Universidade Federal Fluminense, Brazil)

Robust chaos is characterized by the persistence of the chaotic attractor with changes in the system parameters. It is desirable in physical sources of chaotic signals for practical applications of chaos. However, very few continuous time chaotic systems are known that exhibit robust chaos. We are going to present extensive numerical evidence that robust chaos emerges in certain nonlineal systems of practical interest when they are excited by two harmonic signals with different frequencies. We present results on the investigation of two systems: micro and nanoeletromechanical suspended beam resonators and the Duffing oscillator. The results leave the question, for further investigation, about what other dynamical systems can benefit from the two-frequency excitation and develop a robust chaotic attractor.

A New Chaotic Finance System: Its Analysis, Control and Synchronization

Babatunde Idowu

(Lagos State University – Ojo, Nigeria)

A new chaotic finance system was proposed, which is a self-excited chaotic attractor. The phase portraits and qualitative properties of the new chaotic system are described in detail. The control and synchronization of the new chaotic financial system with uncertain parameters was examined using adaptive control and backstepping control techniques. The designed adaptive controller control and globally synchronizes two identical chaotic financial systems evolving from different initial conditions. The designed controller is capable of stabilizing the financial system at any position as well as controlling it to track any trajectory that is a smooth function of time. Numerical simulations are presented to demonstrate the feasibility of the proposed schemes.

Turing Patterns Modulation by Chemical Gradient

Alejandro López-Castillo

(UFSCar, Brazil)

The emergence of Turing patterns modulated by Dirichlet boundary conditions are studied. The boundary conditions can induce spatial symmetry breaking of Turing structures under some conditions. This model could be considered as a minimal model to describe the initial steps of cellular differentiation and embryogenesis.

Non-local coupling among oscillators mediated by fast travelling waves

Raul de Palma Aristides

(UFPR, Brazil)

We propose a general model for coupling among oscillators mediated by wave propagation in the spatial region in which the oscillators are embedded. Particular cases are presented in one, two and three spatial dimensions. We present, as a numerical application, an investigation of phase and frequency synchronization in a lattice of phase oscillators coupled according the general model.

Collective organization of networked phase oscillators: explosive synchronization and Bellerophon states

Stefano Boccaletti

(CNR - Institute of Complex Systems)

I will discuss the spontaneous emergence of some complex collective dynamics in networked phase oscillators.

As a first step, I will discuss how synchronization may emerge in agraph. Synchronization is a process in which dynamical systems adjust some properties of their trajectories (due to their interactions, or to a driving force) so that they eventually operate in a macroscopically coherent way. A common result is that the vast majority of transitions to synchronization are of the second-order type, continuous and reversible. However, as soon as networked units with complex architectures of interaction are taken into consideration, abrupt and irreversible phenomena may emerge, namely explosive synchronization, which rather remind first-order like transitions.

In the second part of my talk, I will concentrate on a recently unveiled coherent state, the Bellerophon state, which is generically observed in the proximity of explosive synchronization at intermediate values of the coupling strength.

Bellerophon states are multi-clustered states emerging in symmetric pairs. In these states, oscillators belonging to a given cluster are not locked in their instantaneous phases or frequencies, rather they display the same long-time average frequency (a sort of effective global frequency). Moreover, Bellerophon states feature quantum traits, in that such average frequencies are all odd multiples of a fundamental frequency.

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Poster – Group 1

Control of synchronization in neural networks: a scale-free model

Adriane da Silva Reis

(Universidade Federal do Paraná)

One of the main constituents of the nervous system are the neurons. They are connected to each other in a complex way, forming a complex network of connections. In this research, will be presented a building model to a neuronal network based on human cerebral cortex, using a real connectivity matrix, obtained trough experimental methods. The study of the construction of the neuronal model will be done using a network of networks, in such a way that connections in each region of the cerebral cortex can be described by a model of small world networks. The cortical networks will be connected to each other according to the type of synapse present in each region, and the neuronal dynamics will be studied through the two-dimensional Rulkov map. Due the individuality of each neuron, they perform their activities in different rhythms so that at first there is no synchronization in their bursts. To study synchronization in the neural network, an external signal was applied on Rulkov's map so that all neurons could start a bursts at the same time. Neuronal synchronization, in general, refers to the presence of some neurodegenerative disease. In this sense, the synchronization suppression technique was employed through the application of a delay field in the neural network. It has been found that the method chosen for the suppression control is efficient to suppress synchronization when the control parameter and the delay time are set appropriately.

Stability in Kuramoto–Sakaguchi Model for a network of identical oscillators

Antonio Mihara

(Universidade Federal de Sao Paulo)

We study the Kuramoto--Sakaguchi model composed by N identical phase oscillators symmetrically coupled. Ranging from local (one-to-one, $R=1$) to global (all-to-all, $R=N/2$) couplings, we derive a general solution that describes the network dynamics close to an equilibrium. Therewith we build stability diagrams according to N and R bringing to the light a rich scenery of attractors, repellers, saddles, and non-hyperbolic equilibriums. Our result also uncovers the obscure repulsive regime of the model through bifurcation analysis.

Modular Structure in C. elegans neural network and its response to external localized stimuli

Carolina Arruda Moreira

(Instituto de Física Gleb Wataghin)

Synchronization plays a key role in information processing in neuronal networks. Response of specific groups of neurons are triggered by external stimuli, such as visual, tactile or olfactory inputs. Neurons, however, can be divided into several categories, such as by physical location, functional role or topological clustering properties. Here we study the response of the electric junction C. elegans network to external stimuli using the partially forced Kuramoto model and applying the force to specific groups of neurons. Stimuli were applied to topological modules, obtained by the ModuLand procedure, to a ganglion, specified by its anatomical localization, and to the functional group composed of all sensory neurons. We found that topological modules do not contain purely anatomical groups or functional classes, corroborating previous results, and that stimulating different classes of neurons lead to very different responses, measured in terms of synchronization and phase velocity correlations. In all cases, however, the modular structure hindered full synchronization, protecting the system from seizures. More importantly, the responses to stimuli applied to topological and functional modules showed pronounced patterns of correlation or anti-correlation with other modules that were not observed when the stimulus was applied to ganglia.

Uncertainty Principle and Semi-quantum Chaos in the SU(2) non-linear Dynamics

Claudia Mónica Sarris

(Facultad de Ingeniería - Universidad de Buenos Aires)

A semi-quantum non-linear Hamiltonian, associated to the SU(2) Lie algebra [1], is used to model the confinement of a spin ½ in the double well potential generated by a classical particle of mass m. This Hamiltonian has two dynamic invariants: the energy and the uncertainty principle, this latter one cannot take arbitrary values. The system exhibits three different zones characterized by the quantity and kind of fixed points that may appear [2]. It is shown how the uncertainty principle restricts the access and system´s evolution in each of the three zones. It is also shown, through numerical simulations, some possible scenarios for the dynamics´ behavior as the uncertainty principle crosses the range of all possible values that it can achieve. Depending on the uncertainty principle invariant´s value and the amount of energy available by the system, it is possible to appreciate regular and chaotic dynamics (semi-quantum chaos) not only in the classical subsystem but also in the quantum one in the three zones mentioned above.

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Cognition and complex networks

Fernando Naranjo Mayorga

(Universidad Pedagógica y Tecnológica de Colombia)

We make a panoramic description of the relationship that complex networks have with cognitive processes. We develop this panorama with a journey through the different scales of cognitive processes, from neuronal systems as functional networks, to collective or social learning processes. It also presents the approach of a problem of interrelation of language and its complex neural network with non-normal child behavior.

Stochastic and deterministic model for co-circulation of dengue and zika virus

Flávia Mayumi Ruziska Hirata

(Instituto de Física da USP)

Since the re-entrace of Dengue in Brazil in ninities, roughly one can say that there are outbreaks of Dengue with interval of about 6 years. After the big outbreak of Zika in 2015/2016, there was not another outbreak of Zika and the number of Dengue cases have also reduced. In 2015/2016, the epidemic scenarios of Zika and Dengue are different from city to city. In order to provide insight about the different scenarios associated with transmission dynamics of simultaneous Dengue and Zika epidemics we have analysed a stochastic model for co-circulation of Zika and Dengue. We have concluded that, if one assumes that a population infected by Zika is less susceptible to Dengue, it can generate scenarios where the outbreaks of Dengue are lower and delayed. We have compared the simulated data produced by the model to the ones generated by its deterministic version. The fluctuations are greater for smaller populations and smaller density of initial infected individuals, and this fact can help to explain the big variability from epidemic data through the cities. We have investigated the relation between the basic reproductive number R0, for deterministic version of the model, and the fraction of cases for which there was no propagation in the stochastic simulations of the model. We also compared the results with epididemic data, and analyzed the influence of the report rate in the conclusions.

Moderate immunization as a tool to efficiently contain spreading on scale-free networks

Guilherme Henrique da Silva Costa

(Universidade Federal de Viçosa)

Many strategies for epidemic containment are focused on maximizing contact network immunization with minimal costs. However, maximal damages are seldom accessible in practice and, more importantly, may present extreme side effects which could be more harmful than the epidemics itself. Little attention has been dedicated to epidemic spreading on networks after immunizations which preserve their structural integrity and functionality. Here, we fill this gap investigating epidemics spreading on immunized scale-free networks where node removal is far below the percolation threshold such that the non-immunized vertices represents a large connected component. Despite of preserving the network integrity, moderate immunization procedures are able to drastically reduce the epidemic prevalence and promote its eradication. In particular, we show that the acquaintance immunization leads to a finite epidemic threshold of fundamental models on synthetic scale-free in contrast with the null threshold found in either absence of immunization or with random strategies. Analyses of several real networks with distinct degrees of heterogeneities and correlations back up our conclusions. Our results pave an alternative way for epidemic containment preserving network functionality by concomitantly reducing the infection rate and immunizing a nonlethal fraction of the network.

Control of Synchronization on Complex Networks of Neurons

João Antonio Paludo Silveira

(UFPR - Universidade Federal do Paraná)

We use the Rulkov Map neuron model to simulate complex networks of neurons with a Small-World architecture and various degrees of synchronization. A sinusoidal external signal is then applied in some neurons of these networks, and its effects on the network synchronization are analyzed. We find that if the network is initially synchronized, the addition of the signal will in general lessen its synchronization, and that this decrease is more impactful if the network is only partially synchronized. We also show that when the signal frequency matches the natural frequency of the network, the synchronization is increased.

Mathematical model of brain tumour growth with drug resistance

JOSÉ TROBIA

(Universidade Estadual de Ponta Grossa, UEPG)

Brain tumors are masses of abnormal cells that can grow uncontrollably in the brain. Tumor cells are abnormal cells classified as benign and malignant. There are different types of malignant brain tumors. Gliomas are malignant brain tumors that grow from glial cells and are separated into astrocytoma, oligodendroglioma, and ependymoma. Glial cells provide support and neuronal protection. Mathematical modeling of tumor growth has been used to understand different aspects of cancer. Several studies have analyzed a mathematical model of cancer treatment by the chemotherapeutic agent, taking into account the metastases. Other studies used a model to study tumor growth undergoing continuous and pulsed chemotherapy. In the literature, it is possible to find different models of brain tumors. In this work we study a mathematical model of a dynamic system of ordinary differential equations, which describes the interaction glia-neuron, glioma sensitive and drug resistant and chemotherapeutic. Treatment of the tumor occurs through continuous or pulsed chemotherapy. Drug resistance in cancer is a major problem in chemotherapeutic treatment because of the ability of cancer cells to develop resistance to chemotherapeutic agents. We have shown that in continuous chemotherapy, neuronal life expectancy depends on the infusion of the chemotherapeutic agent rate and the mutation rate of drug-sensitive cells into drug-resistant cells. With regard to pulsed chemotherapy, we have shown that the chemotherapy cycle and the time interval of application of the drug play important roles in the treatment. In addition, we have shown that drug resistance significantly affects brain tumor growth when different chemotherapy protocols are applied to maximize clearance of glioma cells, thereby minimizing the death of neurons.

Dynamical description of trajectories flux in the phase space for nontwist Hamiltonian systems

Michele Mugnaine

(Federal University of Paraná)

Non-integrable Hamiltonian systems are characterized by the coexistence of regular and chaotic solutions in the phase space: periodic, quasiperiodic, and chaotic orbits mixed together. The study of transport, which aims to describe the motion of groups of trajectories through the phase space, is well established for twist systems and it is known that the dynamical mechanism underlying transport is the partial barriers formed by joining the gaps in invariant Cantor sets. For nontwist systems, we show that the mechanism of the turnstile can increase the flux in nontwist Hamiltonian systems. We study the transport in the standard nontwist map, that is a generic conservative nontwist map taken as a paradigm for the dynamical behavior of nontwist systems in general. In our study we perform numerical computation of the transmissivity through the internal transport barrier and the behavior of the manifolds and turnstiles in those regimes. The high transport scenario are explained by the proximity of heteroclinic points and by an intercrossing of the manifolds between the twin islands chains in both sides of the partial barrier.

How epileptic seizures are generated in a neuronal network model

Paulo Ricardo Protachevicz

(Universidade Estadual de Ponta Grossa)

Since abnormal synchronization is recurrently associated with epileptic seizures, we investigate how the decrease of inhibition can generate neuronal synchronization in a synaptic unbalanced network. About the transition, from desynchronous spike to synchronous burst activity, we find a bistable regime, where the network can exhibit desynchronous spike or synchronous burst depending on the previous activities of the network and external stimulus. Our neuronal network supports both normal and seizure activities. We find larger instantaneous synaptic input and firing rates in synchronous burst than for dessynchronous spike activities. To cease synchronized activity in the bistable regime, we consider a square current pulse with positive and negative amplitudes. The stimulus have different durations and are applied on a percentage of neurons. We verify that the desynchronization is obtained considering both positive and negative amplitudes. However, it is necessary a positive smaller than a negative amplitude value to suppress synchronous behavior. Therefore, we show that the use of electrical stimulation can be an effective treatment for seizures in bistable regime.

Time Recurrence Analysis of a Near Singular Billiard

Rodrigo Simile Baroni

(Universidade Estadual Paulista - Instituto de Geociências e Ciências Exatas)

Billiards exhibit rich dynamical behavior typical of Hamiltonian systems. We investigate the classical dynamics of particles in the eccentric annular billiard, which has a mixed phase space, in the limit that the scatterer is point-like. We call this configuration as the near singular, in which a single initial condition densely fills the phase space with straight lines. To characterize the orbits, two technics were applied. The largest Lyapunov exponent λ was calculated using the paradigmatic Finite Time Lyapunov Exponent (FTLE) FTLE method. Generally, for conservative systems, $\lambda>0$ indicates chaotic behavior and $\lambda=0$, regularity. The recurrence of orbits in the phase space was investigated through recurrence plots. Chaotic orbits show many different return times and, according to Slater's theorem, quasi periodic orbits have at most three different return times, the bigger one being the sum of the other two. We show that after the transition to the the near singular billiard, a typical orbit exhibits a sharp drop in the value of λ and many different recurrence times. The patterns in the recurrence plot reveal that this chaotic orbit is composed of quasi periodic segments. We also conclude that reducing the magnitude of the nonlinear part of the system did not prevent chaotic behavior.

Unitary speed mobile agents in circular symmetric patterns

Vander Luis de Souza Freitas

(National Institute for Space Research)

We perform extensive tests in a model of particles with phase-coupled oscillators dynamics, focusing on the special case in which they rotate around a common center and are able to group into clusters. We consider particles moving in the plane with unitary mass and speed. They are coupled to each other through an all-to-all approach and share their positions and heading angles (phases). As result, the particles develop a concentric circular trajectory and group into uniformly distributed clusters of the same size. We analyze the control parameters' space to find stable regions in which the clusters are well formed. We found that the higher the number of desired clusters, the smaller is the stable region. Additionally, we simulate particles being added/removed to/from already stable formations. It resembles the problem of real world mobile agents that break during an ongoing mission and the opposite situation of new agents being included. We found behavior transitions that depend on the number of new (or removed) particles: before the transition, some particles sit between stable clusters and do not join them; after the transition, all particles join clusters.

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Poster – Group 2

Swimming strategies in two-dimensional flows

Alfredo Manuel Jara Grados

(Universidade Federal do ABC)

Two models of self-propelled particles in a steady two-dimensional flow corresponding to convective cells with transport barriers are studied. The goal is to determine the most efficient model to foster the transport of particles along a predetermined direction. The first model is self propulsion with constant velocity along the predetermined direction and the second model is self propulsion with sinusoidal temporal modulation along that direction. In both cases, the velocity of the particle at any instant is considered to be the sum of the self-propulsion velocity with the velocity of the flow at the position of the particle. The main motivating question is: Which of these models leads to a larger set of initial conditions of trajectories non-confined to a compact domain of the physical space? We use numerical and analytical methods to address this question.

Sychronization of non-identical Hodgkin-Huxley type neurons.

Arturo Cagnato Conte

(Universidade Federal do Paraná)

The study of synchronization in neuronal networks are important to understand the dynamics of the networks and also possible patologies that may be associated with their synchronization or non-synchronization. In this work we study how the diversity of neurons will affect the synchronization of the network using Huber-Braun equations, that are modified from the Hodgkin-Huxley set of neural equations. The connections of the network obey the Small-World regime, which have a high clustering coefficient and a low mean path lenght. We found that even the smallest of changes in the diversity of the system will impact in the synchronization structure of the network.

Dynamical nature of plasma density fluctuations in tokamak TCABR

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One of the factors that compromise the quality of the confinement of magnetically confined plasma is the anomalous transport of particles attributed to the electrostatic turbulence observed at the edge region of the plasma. There is no consensus yet about the dynamical nature of these fluctuations, and it is possible to find in the literature models that treat it as chaotic or stochastic. One of the methods that proposes to distinguish the dynamical nature of fluctuations in time series is the Complexity-Entropy Diagram, a method that has recently been used in several areas, among them Plasma Physics. In this work I shall present the results obtained using this method applied in the ion saturation current signal measured by Langmuir probes in the tokamak TCABR and compare it to published results of similar studies done in other machines.

Quantifying coherence of chimera states in coupled chaotic systems

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Chimera states in coupled oscillator systems present both spatially coherent and incoherent domains. The number and size of these domains depend on many factors like the system parameters and initial conditions. Systematic investigations of these dependences require a quantification of the degree of coherence present in a given snapshot spatial pattern. We propose the use of a local order parameter magnitude combined with the counting of the corresponding plateaus so as to provide such quantification. We use this technique in non-locally coupled lattices of chaotic logistic maps and chaotic Rössler systems to investigate the dependence of the degree of coherence on the coupling strength.

Uncertainty quantification in a nonlinear transmission model for Zika virus

Eber Dantas de Sá Paiva

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Mathematical modeling is an essential tool when simulating vector-borne diseases, which can be used to estimate the size of epidemics and improve control strategies. However, any modeling procedure is prone to uncertainties due to epistemological limitations and data errors. In this work, a general uncertainty quantification framework is presented for the construction of a stochastic epidemic model of propagation. Sensitivity analysis is performed with Sobol indices, via a polynomial chaos expansion of the model. The formalism of the Maximum Entropy Principle is employed to tackle the lack of information, inferring the least biased probability density distributions of the more sensitive parameters. The framework is showcased in a SEIR-SEI compartmental model for Zika virus infection, evaluating its robustness in different stochastic scenarios when contrasting with real data. Results are also presented that regard general parametric behavior revealed by the sensitivity analysis and further considerations on valuable statistics that can be computed from the propagation of uncertainties.

Improving the prediction of extreme seasons in the Lorenz system

Eduardo Luís Brugnago

(Universidade Federal do Paraná)

This work describes the fundamental mathematical property which allow forecasting seasonal changes in the paradigmatic Lorenz system. The alignment of Lyapunov vectors (LVs) along the flow direction preceeds seasonal changes and is able to estimate the time duration of the predicted season. Extreme long seasons durations can be predict by using strong alignment conditions. It is shown that there is a monotonic relation between the alignment of LVs and the predicted season times. Similar results are obtained between Bred vectors (BVs) and the predicted season times. Combining the alignment of LVs and the maxima in the local expansion of BVs allows us to significantly decrease errors in the prediction of season times.

Recurrent Quantidication analysis of the Parana River flood dynamics

Jaques Everton Zanon

(Instituto de Botanica)

Intermittent Turbulence in the Texas Helimak

Felipe Augusto Cardoso Pereira

(UFPR)

The Texas Helimak is a toroidal plasma device with one-dimensional equilibrium, magnetic curvature and shear, resembling closely the border and scrape-off layer of a Tokamak. The Helimak typical regime turbulence presents intermittent high density bursts that are responsible for an assymetrical PDF. This machine has 16 plates, where a large set of Langmuir probes is mounted and from where is possible to impose an external electrostatic bias. This bias can change the turbulence regime, suppressing or enhancing the intermittent bursts, depending on where it is applied and its value. In this work, we study the turbulence regimes with non-linear analysis tools and analyze the statistics of the bursts occurrence times to characterize the intermittent regime.

Synchronization of two-coupled candle flames by diffusion-convection

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(Pontificia Universidad Católica del Perú)

We propose a model that coupling radiating diffusion flame, chemical factors in a convective fluid. This model shows an oscillatory behavior of flame with respect to the Damkhler number. The coupling of two candles producing in-phase and antiphase synchronization that depending on the distance between candles. The results suggest that convection may be an essential factor of the synchronization.

Uncertainty Principle and Semi-quantum Chaos in the SU(2) non-linear Dynamics.

Leonidas Facundo Caram

(Facultad de Ingeniería - Universidad de Buenos Aires)

A semi-quantum non-linear Hamiltonian, associated to the SU(2) Lie algebra [1], is used to model the confinement of a spin ½ in the double well potential generated by a classical particle of mass m. This Hamiltonian has two dynamic invariants: the energy and the uncertainty principle, this latter one cannot take arbitrary values. The system exhibits three different zones characterized by the quantity and kind of fixed points that may appear [2]. It is shown how the uncertainty principle restricts the access and system´s evolution in each of the three zones. It is also shown, through numerical simulations, some possible scenarios for the dynamics´ behavior as the uncertainty principle crosses the range of all possible values that it can achieve. Depending on the uncertainty principle invariant´s value and the amount of energy available by the system, it is possible to appreciate regular and chaotic dynamics (semi-quantum chaos) not only in the classical subsystem but also in the quantum one in the three zones mentioned above. References: [1] J. MA, R. K. YUAN, Semiquantum chaos, Int. J. Phys. Soc. Jpn, Vol 66, No. 8 (1997), pp. 2302-2307. [2] R. HANSEN, C. M. SARRIS & A. PLASTINO, Uncertainty Principle and Bifurcations in the SU(2) Nonlinear Semiquantum Dynamics, Applied Mathematics (AM), Vol. 9, No. 1 (2018), pp 1-16.

Shearless Transport Barriers in Tokamaks

Marisa Roberto

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The internal transport barriers in tokamaks which are produced by plasma current profile modifications can reduce transport and improve plasma confinement. To investigate the shearless barriers that appear in tokamaks we use a non-integrable drift-kinetic model. The chaotic trajectories are numerically obtained by integrating the canonical equations of motion, for large aspct ratio tokamaks. We have verified the influence of different electric field profiles and the influence of non-resonant modes on the appearance of these transporte barriers.

Chaotic transport in symplectic maps: Applications in plasma dynamics

Matheus Palmero Silva

(IF-USP)

In this work, we investigate the consequences of chaotic transport present in the dynamics of symplectic maps, which describes qualitatively effects of the dynamics of confined plasma in tokamaks. The transport considered occurs along the lines of the magnetic field that confine the plasma. The confinement can be enhanced with the introduction of a divertor plate or an ergodic limiter that modify the magnetic configuration. However, in these cases, the transport exhibits interesting anomalous effects. To describe the field lines perturbated by a divertor, we make use the map introduced by Boozer. To describe the lines perturbed by an ergodic limiter, we consider the map introduced by Ullmann. Statistical analysis, provided by the study of the transport for these maps, especially escape distributions, could provide new evidence, at least qualitatively, of how to reinforce the magnetic confinement of plasma.

Data driven inference of model discrepancies in Zika virus dynamics

Michel Antonio Tosin Caldas

(Universidade do Estado do Rio de Janeiro)

Mathematical modeling is useful tool to understand the spread of vector-borne diseases. In fact, with a calibrated model, is possible test the efficiency of measures to combat epidemics. On the other hand, all the calibration processes are affected by model errors, caused by lack of knowledge about some mechanisms of the real system, and errors in data such as under-reporting. In this work, the authors applied a statistical calibration framework based in a metamodelling via Polynomial Chaos Expansion in a SEIR-SEI compartmental system. The PCE parameters are put together in a random vector and Bayesian inversion is employed for parameters identification in a way to capture the uncertainties in model parameters using a set of real data. With this technique is possible study the calibration capability of the model and compare with that of a group of others compartmental models.

Chaotic Motion on Exact Plane Gravitational Waves

Pedro Henrique Barboza Rossetto

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Plane gravitational waves are exact solutions for the full non-linear Einstein's Equations which represents idealized plane-fronted gravitational waves. This work discusses the motion of free particles in such spacetimes. Interesting chaotic behavior is found for certain choices of the parameters describing the wave. More specifically, the geodesic trajectories on the x-y plane is identified to be a particular case of the Hénon–Heiles system.

Using MEMS/NEMS resonators as pseudo-random generators

Wellington Gomes Dantas

(Universidade Federal Fluminense)

We study how MEMS (or NEMS) resonators could be used to generate a sequence of values which have a random distribution and how the archicteture of this mechanisms can influence such distribution. Using an adequate resonator we can obtain some very interesting results concerning a trial to get a mechanical generator for pseudo-random numbers.

Homoclinic and heteroclinic intersections in the restricted three-body problem

Vitor Martins de Oliveira

(IF-USP)

The restricted three-body problem in celestial mechanics concerns the dynamics of a test particle on a gravitational field generated by a two-body system. Historically, numerical and ad hoc mathematical methods were created to deal with the difficulties associated with the problem. In particular, unstable periodic orbits around some of the equilibrium points have been shown to be very important. Moreover, there are invariant manifolds associated with these orbits that are key elements to investigate transport in the system. In this work, we use efficient numerical methods for tracing invariant manifolds in order to investigate the complex and rich dynamics of the planar, circular and restricted version of the problem. Our aim is to discuss homoclinic and heteroclinic intersections that occur between the invariant manifolds of the unstable periodic orbits around the Lagrangian equilibrium points L1 and L2. These intersections are important, for example in space mission designing, because they delimit the set of orbits that can transit from one primary to the other or from the inner to the outer system.