DYNAMICS DAYS
Latin America and the Caribbean

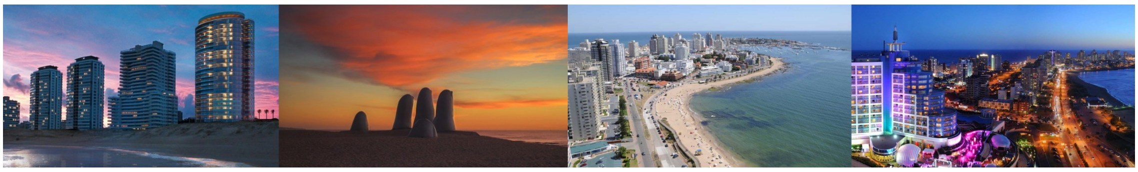
Universidad de la República (UdelaR)
Centro Universitario Regional del Este (CURE), Punta del Este, Uruguay

26–30 November, 2018

Organizers: Prof. Dr. Arturo C. Martí (Chair)
Dr. Nicolás Rubido (Chair)
Federico Abellá
Nicolás Díaz
Dr. Marcelo Forets
Juan Gancio
Caracé Gutiérrez

Welcome Address

Welcome to the *Dynamics Days Latin America and the Caribbean* (DDays LAC) 2018, the fifth such meeting, following those organized in Brazil (2010), Colombia (2012), Chile (2014), and Mexico (2016). On this occasion, the conference is held in the beautiful city of Punta del Este, a peninsula located at the southernmost point in Uruguay, where the Río de la Plata river meets the Atlantic Ocean, and only an hour and a half away from the capital city, Montevideo.



Dynamics Days (DDays) meetings are international conferences on theory and applications of non-linear dynamics. They have been held regularly in Europe since 1980, in the US since 1982, in the Asia-Pacific region since 1999, in Latin America and the Caribbean (LAC) since 2010, and in Central Asia since 2013.

Since its beginnings, a key goal of the DDays LAC has been to promote cross-fertilization of ideas from different areas in non-linear dynamics. In particular, this DDays LAC meeting is deliberately structured to encourage active participation from young scientists, through contributed oral presentations and posters, and it provides ample time for discussion. Consequently, we expect this DDays LAC to be the perfect environment where to strengthen research, disseminate work and outreach, and foster collaborations.

On this occasion, the contributions range from experimental to theoretical research in all areas related to non-linear dynamics, including (but not limited to), chaos, control theory, synchronisation, statistical physics, stochastic processes, complex systems and networks, non-linear time-series analysis, computational methods, fluid dynamics, plasma physics, granular materials, non-linear waves, pattern formation, quantum chaos, population dynamics, game theory, econophysics, neural dynamics, brain networks, systems biology, and dynamical astronomy.

On behalf of the Local Organizing Committee, we sincerely hope that you have a great time and a fruitful meeting.

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Chaos
An Interdisciplinary Journal of Nonlinear Science

Contents

Plenary Talks

Chaos-based Quantum Control

26 Nov
9:45am
Aula Magna

Celso Grebogi
University of Aberdeen, United Kingdom.

Quantum chaos is referred to the study of quantum manifestations of systems that are chaotic in the classical limit. Most previous research in the field of quantum chaos focused on the non-relativistic quantum regime. Recently the field of relativistic quantum chaos has emerged, due to the tremendous development of research on graphene and topological insulators. Phenomena such as relativistic quantum scarring, chaotic scattering, and tunnelling have been explored. The speaker will discuss a number of fundamental issues in relativistic quantum chaos, but from the perspective of quantum control or modulation: how classical chaos can be exploited to harness relativistic quantum behaviours in Dirac fermion and graphene systems? Transport through quantum dot and resonant tunnelling will be used as two prototypical examples to illustrate the principle that chaos-based quantum control can be advantageous and experimentally feasible.

Robust chaos: a tale of blenders, their computation, and their destruction

26 Nov
10:30am
Aula Magna

Hinke Osinga
The University of Auckland, New Zealand.

A blender is an intricate geometric structure of a three- or higher-dimensional diffeomorphism. Its characterising feature is that its invariant manifolds behave as geometric objects of a dimension that is larger than expected from the dimensions of the manifolds themselves. We introduce a family of three-dimensional Henon-like maps and study how it gives rise to an explicit example of a blender. The map has two saddle fixed points. Their associated stable and unstable manifolds consist of points for which the sequence of images or pre-images converges to one of the saddle points; such points lie on curves or surfaces, depending on the number of stable eigenvalues of the Jacobian at the saddle points. We employ advanced numerical techniques to compute one-dimensional stable and unstable manifolds to very considerable arclengths. In this way, we not only present the first images of an actual blender but also obtain a convincing numerical test for the blender property. This allows us to present strong numerical evidence for the existence of the blender over a larger parameter range, as well as its disappearance and geometric properties beyond this range. We will also discuss the relevance of the blender property for chaotic attractors. This is joint work with Stephanie Hittmeyer and Bernd Krauskopf (University of Auckland) and Katsutoshi Shinohara (Hitotsubashi University).

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26 Nov
11:45am
Aula Magna

Inducing dreams in oscine birds

Gabriel Mindlin

Universidad de Buenos Aires, Argentina.

The coordination of complex vocal behaviors like oscine birdsong require fine interactions between sensory and motor programs. Here we show that in sleeping male zebra finches (Taeniopygia guttata), the activity of the song system selectively evoked by playbacks of their own song can be detected in the syrinx. Electromyograms (EMG) of a syringeal muscle show playback evoked patterns similar to those recorded during song production. Using this readout we studied the activation elicited by different auditory stimuli. We found that synthetic versions of the bird's song, rendered by a physical model of the avian phonation apparatus, evoked similar patterns. Modifications of autogenous or synthetic songs reduce the response probability, but when present, the elicited activity patterns match execution patterns. This builds on previous work, where spontaneous, song-like patterns were observed during sleep, at the level of the syrinx.

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26 Nov
4:00pm
Aula Magna

Extreme events in turbulence: the case of stratified flows

Pablo Mininni

Universidad de Buenos Aires, Argentina.

The definition of what an extreme event is can be different depending on the physical problem considered. In fluid dynamics, the phenomenon of intermittency is the sine qua non of turbulence, and calls for a precise definition of extreme events and for the development of specific theoretical tools to study them. Indeed, the complexity of a turbulent flow is often associated with the fact that turbulence comes in intermittent gusts. These intermittent gusts (or extreme events) are associated with non-Gaussian statistics of some physical quantity in the system. As such, intermittency is a highly spatially- and temporally-localized phenomenon, which thus requires high-resolution instrumentation, be it in the laboratory, in atmospheric observations, or in numerical simulations. In this talk I will discuss some tools from statistics and from dynamical systems that are regularly used to study intermittency and extreme events, including probability density functions of field increments, structure functions, and scaling exponents. As a particular example, I will focus on the problem of vertical drafts and mixing observed in stratified flows. In this problem, for values in parameter space relevant for the atmosphere and the oceans, I will show that non-stationary very large fluctuations of the vertical velocity take place spontaneously in the flow. This behavior can be captured by a simple model representing the competition between gravity waves on a fast time-scale, and non-linear steepening on a slower time-scale. The existence in these flows of a resonant regime characterized by enhanced large-scale intermittency, can then linked to the emergence of specific structures in the velocity and potential temperature fields.

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

26 Nov
4:45pm
Aula Magna

José S. Andrade Jr.

Departamento de Física, Universidade Federal do Ceará, Brazil.

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.

It Dont Mean a Thing, If It Aint Got That Swing: Time Series Analysis of a Mystery

26 Nov
6:45pm
Ralli Museum

Theo Geisel

Max Planck Institute for Dynamics and Self-Organization, Germany.

The so-called swing feeling in jazz performances has puzzled musicologists and jazz critics for decades. For a long time it was believed that one can feel it, but one cannot explain it. More recently discussions focused on the role of microtiming deviations. Can we characterize this phenomenon using tools of nonlinear dynamics and statistical physics?

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27 Nov
9:00am
Aula Magna

Reaction diffusion dynamics and the Landau Lifshitz Gilbert equation for ferromagnetic domain walls

M. Cristina Depassier
Pontificia Universidad Católica de Chile, Chile.

The evolution equation for the magnetization $\vec{M}$ of a ferromagnetic material is the Landau-Lifshitz-Gilbert (LLG) equation

$$\frac{\partial \vec{M}}{\partial t} = -\gamma_0 \vec{M} \times \vec{H}_e(M) + \alpha \frac{\vec{M}}{|\vec{M}|} \times \frac{\partial \vec{M}}{\partial t}$$

where the effective field H_e includes the external field and the effective field due to spin interactions. We study the asymptotics of this equation for ferromagnets with an easy plane and in-plane easy axis. Two regimes are found, depending on the strength of the easy plane. For moderately strong easy plane the dynamics can be reduced to a reaction diffusion equation and the speed of the domain walls increases linearly with the applied field. Similar results have been found for thin nanotubes. The approach followed allows to include the Dzyaloshinski Moriya interaction which modifies the magnetization profile but not the speed. For a stronger easy plane the dynamics is governed by a hyperbolic reaction diffusion equation which predicts that the speed at first increases linearly with the applied field and then reaches a plateau. This behavior describes what has been observed numerically and experimentally in some materials. Work in progress for thin nanotubes will also be described where we expect similar behavior. In both, the moderate and strong easy plane cases, a transition from pushed to a pulled front is found as the applied field increases beyond a critical value which depends on the uniaxial anisotropy constant. This transition slows down the domain wall.

We shall also discuss the relation of the exact Walker solution to reaction diffusion dynamics and explain its recently found instability as the magnetic field increases beyond a critical value as a transition from a pushed to a pulled regime.

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27 Nov
9:45am
Aula Magna

Interdependence and competition in dynamical multilayer networks

Stefano Boccaletti[1], I. Bonamassa[2], M. M. Danziger[2], and S. Havlin[2]
[1]CNR-Institute of Complex Systems, Italy; [2]Bar-Ilan University, Israel.

From critical infrastructure, to physiology and the human brain, complex systems rarely occur in isolation. Instead, the functioning of some nodes in one system often promotes or inhibits the functioning of other nodes in another. I will illustrate a broadly applicable framework for interdependency and competition among dynamical units, and will discuss specific applications to synchronization and spreading processes in multilayer networks with interacting layers. Novel collective phenomena (which are absent in the isolated counterparts) are illustrated, including multi-stability, regions of coexistence, and macroscopic chaos. In interdependent dynamics, hysteretic behaviors with abrupt (hybrid and explosive) transitions appear, with universal dynamics that match interdependent percolation.

The calcium signaling dilemma: to propagate or not

28 Nov
9:00am
Aula Magna

Silvina Ponce Dawson
DF FCEN-UBA, IFIBA CONICET, Argentina.

Calcium signals are ubiquitous. They are involved in a large variety of physiological processes. The versatility of calcium ions as a signaling agent relies on the variety of spatio-temporal distributions that the intracellular calcium concentration can display. While some signals remain spatially localized others propagate throughout the cell and even between cells to convey their message. Cells have different strategies to change the properties of their intracellular signals depending on various factors. In this talk I will discuss the main biophysical processes that underlie intracellular calcium signals and how they can be varied to elicit different signal types. I will focus, in particular, on the changes that occur during the maturation that transforms an oocyte into an egg that can eventually be fertilized, a process that requires the correct propagation of an intracellular calcium wave to start the sequence of cell divisions that leads to the formation of the embryo.

Signal encoding and transmission by noisy coupled neurons

28 Nov
9:45am
Aula Magna

Maria Masoliver and Cristina Masoller
Universitat Politécnica de Catalunya, Spain.

Sensory neurons encode and transmit information of external inputs in their spike sequences; however, how the information of a weak signal is encoded in the presence of noise remains poorly understood. Different encoding mechanisms can be expected to be functional under different conditions. In this talk I will focus on a conceptually simple problem: how neurons encode a weak periodic input? First, I will focus in an individual neuron. I will present results of simulations of the stochastic FitzHugh-Nagumo (FHN) model that suggest that, when the neuron perceives the signal, it can encode it's period and amplitude in the probabilities of more-expressed and less-expressed spike patterns, which are defined by the relative timing of the spikes [1]. Then, I will discuss how a second neuron, which does not perceive the signal, affects the detection and the encoding of the signal, done by the first neuron. I will present results of simulations of two noisy FHN neurons. Simulations suggest that the neuron that perceives the signal fires a spike train which also has preferred and infrequent patterns carrying the signal information [2]. Therefore, signal encoding in symbolic spike patterns is robust to coupling, and thus, it can be a plausible mechanism of signal encoding. Finally, I will discuss ongoing efforts devoted to understand the encoding of weak signals by small ensembles of neurons, with modular coupling structure.

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28 Nov
11:00am
Aula Magna

Life at the edge: complexity and criticality in biological function

Dante R. Chialvo

Center for Complex Systems & Brain Sciences (CEMSC3), Universidad Nacional de San Martin, Argentina

Why life is complex and –importantly– what is the origin of the over abundance of complexity in nature. This is a fundamental scientific question which, paraphrasing the late Per Bak, is screaming to be answered but seldom is even being asked. In this lecture we review successful attempts to understand the origins of complex biological problems from the perspective of critical phenomena. To illustrate the approach across three scales cases are discussed, namely the large scale brain dynamics, the characterisation of spontaneous fluctuations of proteins and the complexity of the cell mitochondria network.

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28 Nov
11:45am
Aula Magna

Detecting dynamic spatial correlation with generalized wavelet coherence and non-stationary surrogate data

Mario Chávez

CNRS-UMR 7225, France.

Time series measured from real-world systems are generally noisy, complex and display statistical properties that evolve continuously over time. Here, we present a method that combines wavelet analysis and non-stationary surrogates to detect short-lived spatial coherent patterns from multivariate time-series. In contrast with standard methods, the surrogate data used here are realisations of a non-stationary stochastic process, preserving both the amplitude and time-frequency distributions of original data. We evaluate this framework on synthetic and real-world time series, and we show that it can provide useful insights into the time-resolved structure of spatially extended systems.

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28 Nov
2:00pm
Aula Magna

Delayed Dynamical Systems and Networks

Rajarshi Roy

University of Maryland, College Park, United States.

Experiments on networks of coupled nonlinear oscillators are few and far between. A new experimental technique to generate networks of dynamical systems, small and large, with arbitrary coupling topology is described. This technique utilizes a space-time mapping of time-delay systems together with field programmable gate arrays (FPGA). Several aspects (advantages and limitations) of this technique are the ability to configure arbitrary networks (unidirectional or bidirectional), introduce controlled noise, and change network connections as desired. The dynamical nodes can be truly identical or non-identical and heterogeneous as desired. Larger networks slow down the operation of the system and are limited by the resources of

the FPGAs employed. Our current experiments involve up to a few hundred nodes. Initially the system was demonstrated for networks of coupled maps; this has been extended to continuous time systems, and we will give examples of both types of operation. A recent effort has been made to implement reservoir computing processes on this experimental system. This may lead to hardware implementations of reservoir computing for specific problems.

Synchronization in populations of moving oscillators

29 Nov
9:00am
Aula Magna

Albert Diaz-Guilera
Universitat de Barcelona, Spain.

Here we will show results obtained in our group concerning synchronization of populations of moving oscillators. On the one hand, populations of identical Kuramoto oscillators that move randomly on a plane, without considering excluded volume effects, enables to obtain analytical results for the time needed to synchronize [1]; later on, we hace extended this framework to locally interacting self-propelled particles for which synchronization generically proceeds through coarsening verifying the dynamic scaling hypothesis, with the same scaling laws as the the 2d XY model following a quench [2]. Our results shed light into the generic nature of synchronization in time- dependent networks, providing an efficient way to understand more specific situations involving interacting mobile agents. Alternatively, we have also investigated synchronization in populations of integrate and fire oscillators, showing that under restrictive conditions of connectivity, the time needed for the population to synchronize is not a monotonous function of velocity [3, 4].

[1] N. Fujiwara, J. Kurths, and A. Diaz-Guilera, PRE 83, 025101(R) (2010)
[2] D. Levis, I. Pagonabarraga, and A. Diaz-Guilera, PRX 7, 011028 (2017)
[3] L. Prignano, O. Sagarra, and A. Daz-Guilera, PRL 110, 114101 (2013)
[4] A. Beardo, L. Prignano, O. Sagarra, and A. Daz-Guilera, PRE 96, 062306 (2017)

Analysis of pedestrian evacuations: models and experiments

29 Nov
9:45am
Aula Magna

Marcelo Kuperman
Centro Atómico Bariloche and Instituto Balseiro, Argentina.

When formulating the safety guidelines included in building codes the exit capacity in case of evacuation is among the critical parameters that must be considered. Most of the times, this capacity is consigned in terms of solely the exit times or equivalently the mean pedestrian flow rate through the designed exits.

In this presentation we show that this measure may not provide an accurate characterization of an evacuating scenario and that an assessment of the fluctuations that occur during such process might provide a more sensitive and valuable information. For this reason, we suggest a simple way to partially assess the extent of information derived from these fluctuations on the basis of the statistical characterization of the time gaps between successive escapes through a door. We present both numerical and experimental results that while delimiting the validity range of the previous proposal, show that in any case it is better than only the measurement of the mean exit capacity.

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30 Nov
9:00am
Aula Magna

Predictability of Extreme Climate Events via a Complex Network Approach

Jürgen Kurths

Humboldt University Berlin and 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.

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. Applying this method, we uncover a new mechanism of extreme floods in the eastern Central Andes which could be used for operational forecasts. Moreover, 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.

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30 Nov
9:45am
Aula Magna

Fundamental energy limits in the physics of memories

Luca Gammaitoni[1], I. Neri[1], D. Chiuchiù[2], M. López-Suárez[1] and M. C. Diamantini[1]

[1]Università degli studi di Perugia, Italy; [2]Okinawa Institute of Science and Technology, Japan.

Preservation of memory plays a fundamental role in many aspects of human experience. In 1961, Rolf Landauer pointed out that resetting a binary memory requires a minimum energy of $k_B T \ln(2)$. However, once written, any memory is doomed to loose its content if no action is taken. To avoid memory losses, a refresh procedure is periodically performed. In this talk we present a theoretical and experimental study of sub-$k_B T$ system to evaluate the minimum energy required to preserve one bit of information over time. Two main conclusions are drawn: i) in principle the energetic cost to preserve information for a fixed time duration with a given error probability can be arbitrarily reduced if the refresh procedure is performed often enough; ii) the Heisenberg uncertainty principle sets an upper bound on the memory lifetime: no memory can last forever.

Contributive Talks

Plasticity in neuronal networks

26 Nov
2:00pm
Room 5

Antonio M. Batista[1], Kelly Iarosz[2], Rafael Borges[3], Fernando Borges[4], Ewandson Lameu[5], Paulo Protachevicz[1], Jose Szezech[1], Iberê L. Caldas[2], Chris Antonopoulos[6] and Murilo S. Baptista[7]

[1]State University of Ponta Grossa, Brazil; [2]University of São Paulo, Brazil; [3]Federal University of Technology-Paraná, Brazil; [4]Federal University of ABC, Brazil; [5]National Institute for Space Research, Brazil; [6]University of Essex, United Kingdom; [7]University of Aberdeen,United Kingdom.

Brain plasticity, also known as neuroplasticity, is a fundamental mechanism of neuronal adaptation in response to changes in the environment or to new situations. The research about plastic brain is in the science's 10 hottest fields. We have been studying synchronous and non synchronous states dependence on the brain plasticity. The synchronisation of neuronal activity happens when neurons are actived at the same time, namely assemblies of neurons fire simultaneously. We also analyse the influence of synaptic plasticity on the network topology. We show that spike timing-dependent plasticity induces topological complexity in the brain.

Act and wait concept meets oscillating delayed feedback control

26 Nov
2:00pm
Room 6

Verónica Estela Pastor and Graciela Adriana González

Universidad de Buenos Aires

The act-and-wait concept developed by Insperger [1] is the periodic switching in and off control with delay. Its advantage is that if the wait-time is longer than the feedback delay, the dynamics of the controlled system with delay is described by a discrete time system without delay. Based on this concept, a delayed feedback controller has been designed in [2] for equilibrium point stabilization. This controller depends on four parameters: the control gain, the delay, the control period and the wait time. It has been implemented for a prototype two dimensional oscillator but its successfulness for any case has not been guaranteed. Namely, it is easy to see that in the scalar case, it does not work for any set of control parameters. This is not a limitation for the oscillating delayed feedback control with two delayed states developed in [3] which depends only on the control gain and the delay. In this work, it is considered the introduction of a control period and a wait time into the oscillating delayed feedback control and it is studied how these parameters influence on the control method achievements and performance.

References

[1] T. Insperger and G. Stepan. On the dimension reduction of systems with feedback delay by act-and-wait control. IMA Journal of Mathematical Control and Information, **27(4)**, 457473 (2010)

[2] H. Konishi, K. Kokame and N. Hara. Delayed feedback control based on the act-and-wait concept. Nonlinear Dynamics, **63(3)**, 513519 (2011)

[3] V. E. Pastor and G. A. González. Analysis and comparison of two oscillatory feedback control schemes for stabilizing equilibrium points. Proceeding Series of the Brazilian Society of Computational and Applied Mathematics, **4** N 1, 010016-1 – 010016-7 (2016).

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26 Nov
2:00pm
Aula Magna

Detection of time reversibility in time series by ordinal patterns analysis

Johann Martínez[1], Jose Luis Herrera Diestra[2] and Mario Chávez[2]

[1] Institut du Cerveau et de la Moelle Epinière, France; [2]South American Institute for Fundamental Research, Brazil; [3]Hôpital Pitié Salpêtrière, France.

Most systems are inherently nonlinear in Nature, thus detecting this property is of full interest in natural or social sciences. One feature that ensures the nonlinear character of a system is the so-called time irreversibiliity. Although, theoretically, a system is irreversible if its statistical properties change with respect to time direction, its evaluation is still an open problem. Here we propose the Time Reversibility from Ordinal Patterns method (TiROP) to assess the temporal symmetry of linear and nonlinear systems. Our approach is symbolic-based, fast-computing, with no further assumptions about the data, and useful for any natural or synthetic system at different scales. TiROP is compared with a very known test in a rich variety of synthetic models, and tested on real systems, e.g., ecology, epidemic, economy and neuroscience. Our results confirm how TiROP has a remarkable performance at unveiling the time scales involved in the temporal irreversibility of a broad range of processes.

Experiments and low dimensional models to study neural dynamics in songbirds

26 Nov
2:30pm
Room 5

Ana Amador, Santiago Boari, Cecilia T. Herbert, Rodrigo G. Alonso and Gabriel B. Mindlin

University of Buenos Aires, Argentina.

Birdsong is a complex motor activity that emerges from the interaction between the peripheral system, the central nervous system and the environment. The similarities to human speech, both in production and learning, have positioned songbirds as unique animal models for studying the production and perception of this learned motor skill.

In this work, I will present a low dimensional dynamical system as a model of the avian neural network for song production. We developed a neural model in which the variables were the average activities of different neural populations within the nuclei of the song system. We performed electrophysiological experiments to record neural activity from one of these nuclei and found that the low dimensional model could reproduce the neural dynamics observed. Also, this model could reproduce the respiratory motor patterns used to generate song. We showed that sparse activity in one of the neural nuclei could drive a more complex activity downstream in the network. This interdisciplinary work shows how low dimensional models can be a valuable tool for studying the emergence of complex motor tasks.

Coupling and feedback effects in the dynamics of semiconductor lasers

26 Nov
2:30pm
Room 6

Wendson Barbosa[1], Edison Rosero[1], Antonio Khoury[2], Jorge Tredicce[3] and Jose Rios Leite[1]

[1]Universidade Federal de Pernambuco, Brazil; [2]Universidade Federal Fluminense, Brazil; [3] Universite de la Nouvelle Caledonie, Brazil;

Delayed optical feedback applied to semiconductor lasers has proved to induce an enormous variety of effects on its dynamics including from periodic to chaotic pulsations. The synchronism between these chaotic lasers can be achieved combining coupling and optical feedback. We shall describe experimental and theoretically the synchronism between two coupled lasers with optical feedback and its positive and negative correlations [1]. We also show the dynamical changes in the power fluctuation of a diode laser subjected to more than one optical feedback when some controlled parameters are changed.

References

[1] Frustrated Instabilities in Nonlinear Optical Resonators E. J. Rosero, W. A. S. Barbosa, J. F. Martinez Avila, A. Z. Khoury and J. R. Rios Leite, Phys. Rev. E. **94**, 032210, (2016).

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26 Nov
2:30pm
Aula Magna

Detecting causal relations from real data experiments by using recurrence

Elbert Macau[1], Antonio Mario Ramos[1], Jürgen Kurths[2] and Norbert Marwan[2]

[1]National Institute for Space Research, Brazil; [2]Potsdam Institute for Climate Impact Research, Germany.

In this work, we present the Recurrence Measure of Conditional Dependence (RMCD), a recent data-driven causality inference method using the framework of recurrence plots. The RMCD incorporates the recurrence behavior into the transfer entropy theory. We apply this methodology to some paradigmatic models and to investigate the possible influence of the Pacific Ocean temperatures on the South West Amazon for the 2010 and 2005 droughts. The results reveal that for the 2005 drought there is not a significant signal of dependence from the Pacific Ocean and that for 2010 there is a signal of dependence of around 200 days. These outcomes are confirmed by the traditional climatological analysis of these episodes available in the literature and show the accuracy of RMCD inferring causal relations in climate systems.

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26 Nov
3:00pm
Room 5

Spike and burst synchronisation in cortico-cortical network of the human brain

Kelly Iarosz[1], Paulo Protachevicz[2], Rafael Borges[3], Fernando Borges[4], Iberê L. Caldas[1], Ewandson Lameu[5], Fabiano Ferrari[6], Moises Santos[2], Antonio M. Batista[2] and Jürgen Kurths[7]

[1]University of São Paulo, Brazil; [2]State University of Ponta Grossa, Brazil; [3]Federal University of Technology-Paraná, Brazil; [4]Federal University of ABC, Brazil; [5]National Institute for Space Research, Brazil; [6]Federal University of Vales do Jequitinhonha e Macuri, Brazil; [7]Humboldt University, Germany.

The human brain controls many body functions, manages our thoughts, memory, speech, movement and all the organs of our body. It is estimated that the human brain contains about 10^{11} neurons, where each neuron is connected to approximately 10^4 other neurons. The occurrence of synchronisation in some specific areas of the brain may be associated with some diseases, such as epilepsy, lesions, Alzheimer and Parkinsons disease. On the other hand, it is also responsible for some vital brain functions, such as processing of sensory information and motor function. With this in mind, We will present a network topology according to the cortico-cortical connection network of the human brain, where each cortical area is composed of a random network of adaptive exponential integrate-and-fire neurons. Depending on the parameters, this neuron model can exhibit spike or burst patterns. As a diagnostic tool to identify spike and burst patterns, we utilise the coefficient of variation of the neuronal inter-spike interval. In our neuronal network, we verify the existence of spike and burst synchronisation in different cortical areas. Our simulations show that the network arrangement, i.e., its rich-club organisation, plays an important role in the transition of the areas from desynchronous to synchronous behaviours.

Global Bifurcations in Two Nonlinear Coupled Photonic Nanocavities

26 Nov
3:00pm
Room 6

Andrus Giraldo[1], Bernd Krauskopf[1], Neil G. R. Broderick[1], Alejandro M. Yacomotti[2] and Juan A. Levenson[2]

[1]The University of Auckland, New Zealand; [2]Centre for Nanosciences and Nanotechnology, France.

Recent experiments have shown that two coupled photonic crystal (PhC) nanocavities exhibit spontaneous symmetry breaking and bistable behaviour. In particular, bistability has been studied in the last decades due to its usefulness for optical memories and logical switching. Theoretically, bistability and symmetry breaking have been observed in the Bose–Hubbard model, which describes the dynamics of the two coupled PhC nanocavities.

We consider an extension of the Bose–Hubbard model for the slowly varying amplitudes A and B of the electric fields in each nanocavity. It is given as a set of two complex ordinary differential equations determined by a photon lifetime τ, linear couplings between the cavities κ and γ, a detuning from the cavity resonance δ, and a coherent driving term f. Previous work on this model has centered on delimiting regions in the (κ, f)-parameter plane where symmetric and asymmetric continuous-wave solutions exist.

Our work focusses on the overall dynamics of this extended Bose–Hubbard and, in particular, the existence and disappearance of self-pulsations. As more energy is pumped into the system, represented by an increase of the coherent driving term f, self-pulsations arise from Hopf bifurcations, which then disappear in sequences of homoclinic bifurcations. In particular, we find chaotic Shilnikov bifurcations and the appearance of chaotic attractors. We present the overall changes of this system, from simple to chaotic dynamics, as a function of the coherent driving term and the detuning from the cavity resonance. We pay particular attention to how the basins of attraction of the cavities change, and how Shilnikov bifurcations are organized when two parameters are varied.

Spatio-temporal causality for data-specific information modelling

26 Nov
3:00pm
Aula Magna

Murilo S. Baptista

University of Aberdeen, United Kingdom.

Causality lies at the heart of the scientific method. I will show in this talk that causality specifies how information about one variable past or future state in a system depends not only on the time-interval considered but also on the resolution of measurements taken on another variable. This spatio-temporal character of causality offers more data-specific ways of calculating information flow among variables from data, further allowing to make the best possible predictions about the states of variables in a system. This talk will then show how to exploit this dual nature of causality to create informational-theoretical modellings of real-world complex systems (e.g. neural networks, geophysical events, and political-social-economic data), when only a few samples of high-resolution data points or a long-time series of low-resolution data points are available.

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27 Nov
11:00am
Room 4

Sudden transition to large amplitude oscillations: Routes to Extreme events

Syamal K Dana and Arindam Mishra

Jadavpur University, India.

Extreme events create devastation to life and economy. Understanding the origin of extreme events is extremely important for mitigating disaster with an early prediction. Attempts have been made to understand the origin of extreme events using simple dynamical systems first and then to search for a technique to predict, which is a very difficult task. In this talk, I present three major dynamical processes of sudden transitions to large amplitude oscillations via crisis-induced intermittency, Pomeau-Manneville intermittency and breakdown of quasiperiodic motion. We present our observations in a forced Lienard system and a coupled neuron model that show evidence of above three general routes to sudden amplitude explosion leading to extreme events.

References:

1. Arindam Mishra, Suman Saha, M. Vigneshwaran, Pinaki Pal, Tomasz Kapitaniak, and S. K. Dana, Phys. Rev. E 97, 062311 (2018).

2. S. Leo Kingston, K.Thamilamaran, P. Pal, U. Feudel and S. K. Dana, Extreme events in the forced Linard system, Phys. Rev. E 96, 052204 (2017).

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27 Nov
11:00am
Room 6

Cooperation risk and Nash equilibrium: quantitative description for realistic players in the prisoner's dilemma

Guilherme Contesini, Gilberto Nakamura and Alexandre Martinez

University of São Paulo, Brazil

The emergence of cooperation figures among the main goal of game theory in competitive-cooperative environments. Potential games have long been hinted as viable alternative to study realistic players behavior. Here, we expand the potential games approach by taking into account the inherent risks of cooperation. We show the Prisoner's Dilemma is written as Ising Hamiltonian with the correct Nash Equilibrium as the ground state and pertinent phase transitions.

Synchronization of oscillators witn nonlocal coupling mediated by the diffusion of a substance

27 Nov
11:00am
Aula Magna

Ricardo L. Viana[1], Carlos Batista[1], José Szezech Jr.[2], Antonio M. Batista[2], Elbert Macau[3], Fábio Silva[4], Raul Aristides[1], Kelly Iarosz[5]

[1]Universidade Federal do Paraná, Brazil;[2]Universidade Estadual de Ponta Grossa, Brazil;[3]Instituto Nacional de Pesquisas Espaciais, Brazil; [4]Instituto Federal do Paraná, Brazil; [5]Universidade de São Paulo, Brazil.

Many dynamical systems of physical and biological interest can be modeled by phase oscillators. The synchronization of coupled oscillators occurs if the coupling strength is strong enough and if the coupling range is sufficiently large. I will present numerical and analytical results on the synchronization of populations of phase oscillators with a nonlocal coupling which is mediated by the diffusion of some chemical substance in the medium in which the oscillators are embedded.

Extreme multistability in an adjustable Josephson Junction model

27 Nov
11:30pm
Room 4

Patrick Loudop[1], Robert Tchitnga[1], Fernando F. Fagundes[2], Michaux Kountchou[1], Victor Kamdoun Tamba[1], Carlos L. Pando[3] and Hilda A. Cerdeira[4]

[1]Universiteé de Dschang, Cameroon; [2]University of São Paulo, Brazil; [3]Benemérita Universidad Autónoma de Puebla, Mexico; [4]Universidade Estadual Paulista, Brazil.

We design and report of a Josephson Junction (JJ) based chaotic circuit for which the overall state equations surprisingly recall those of a well known “ordinary” model of Josephson junction (OJJ) initially introduced in our circuit just as a single electronic component. The final circuit building an adjustable model of Josephson junction (AJJ) is characterized by the presence of two new and different current sources in parallel with the nonlinear internal current source $sin(\phi(t))$ of the Josephson junction single electronic component (OJJ). The proposed model allows the visualization of the time history of the OJJ phase $\phi(t)$ and limits it in a bounded domain. Furthermore, the model presents an interesting double extreme multistability that can be justified by the infinite of initial conditions.

An iterative estimation for disturbances of semi-wavefronts to the delayed Fisher-KPP equation

27 Nov
11:30am
Room 6

Rafael Benguria and Abraham Solar

Pontificia Universidad Catolica de Chile, Chile.

We give an iterative method to estimate the disturbance of semi-wavefronts of the equation: $\dot{u}(t,x) = u''(t,x) + u(t,x)(1 - u(t-h,x)),\ x \in \mathbb{R},\ t > 0$; where $h > 0$. As a consequence, we show the exponential stability, with an unbounded weight, of semi-wavefronts with speed $c \geq 2\sqrt{2}$ and $h > 0$. Under the same restriction of c and h, the uniqueness of semi-wavefronts is obtained.

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27 Nov
11:30am
Aula Magistral

Synchronization induced by delayed feedback in a network of bursting oscillators

Fabiano Ferrari[1], Kelly Iarosz[2], Adriane Reis[3], Iberê Caldas[2], Ricardo Viana[3], Danilo Szezech Jr.[4] and Antonio M. Batista[4]

[1]Federal University of Jequitinhonha's and Mucuri's Valleys, Brazil; [2]University of São Paulo, Brazil; [3]Federal University of Paraná, Brazil; [4]State University of Ponta Grossa, Brazil.

Coupled bursting neurons can exhibit phase synchronization. They can be represented by a network of coupled Rulkov maps. Typically, the neurons evolve from an asynchronous state to a partial synchronized state, as the coupling strength is increased. The coupling strength value that characterizes the transition from an asynchronous to a partial synchronized state is called critical value. The application of an external perturbation can either increase or decrease the synchronization level in the system. In this work, we present an atypical type of neuronal synchronization where the system synchronizes due to the application of a delayed feedback signal. We call attention to this phenomenon because it occurs before the critical value. The atypical synchronization depends on the local dynamics parameters. We also present a method to identify the critical parameter value where this synchronization appears. We thanks CNPq for partial financial support.

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27 Nov
12:00pm
Room 4

Abundant continuous dynamical systems with infinite-entropy ergodic measures

Eleonora Catsigeras

Universidad de la República, Uruguay.

We prove that the ergodic continuous dynamical systems with infinite entropy are abundant, i.e. "generic"in the sense of Baire cathegory classification. This is a joint work with Serge Troubetzkoy.

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27 Nov
12:00pm
Room 6

Exploration of the nonlinear stochastic dynamics of a bi-stable energy harvester

Americo Cunha Jr, João Peterson and Vinícius Lopes

Universidade do Estado do Rio de Janeiro, Brazil.

Energy harvesting is a very promising technology to provide low levels of power for small autonomous systems, which the applicability encompass a very wide range of areas, that spans from micro/nano sensors in engineering to state of art implants in medicine. Motivated by this context, the present work proposes to explore in deep the nonlinear stochastic dynamics of a bi-stable energy harvester. In particular, it is of interesting to investigate the effects of model parameters uncertainties on the energy harvesting process efficiency, as well as the influence of forcing noise intensity.

It presents the construction of a consistent stochastic model of uncertainties to describe the nonlinear dynamic behavior of this bi-stable system. The physical system of interest consists of a energy harvesting device based on a piezo-magneto-elastic beam, subject to effects of large displacements, modeled by a system of 3 nonlinear differential equations. The underlying uncertainties are take into account through a parametric probabilistic approach, where model parameters are described as random variables and realizations of the random external excitation are constructed via Karhunen-Loève decomposition. Monte Carlo method is employed to compute the propagation of uncertainties through the stochastic model. Numerical experiments show that the system randomness may be beneficial or not the harvester efficiency.

Neuron dynamics variability and anomalous phase synchronization of neural networks

27 Nov
12:00pm
Aula Magistral

Bruno Rafael Reichert Boaretto[1], Roberto C. Budzinski[1], Thiago De Lima Prado[2] and Sergio Roberto Lopes[1]

[1]Universidade Federal do Paraná, Brazil; [2]Universidade Federal dos Vales do Jequitinhonha e Mucuri, Brazil.

Anomalous phase synchronization describes a synchronization phenomena occurring even for weakly coupled network and characterized by a non-monotonous dependence of the synchronization strength on the coupling strength. Its existence may support a theoretical framework to some neurological diseases, such some episodes of seizure behavior generated by epilepsy and Parkinson. Despite the success of suppress the anomalous phase synchronization in neural networks applying external perturbations or inducing ambient changes, the origin of the anomalous phase synchronization as well as the mechanisms behind the suppression are not completely known. Here, we consider networks composed of $N = 2,000$ coupled neurons in a small-world topology for two well known neuron models, namely a Hodgkin-Huxley like and a Hindmarsh-Rose models, both displaying anomalous phase synchronization regime. We show that the anomalous phase synchronization may be related to the individual behavior of the coupled neurons, particularly we identify a strong correlation between the behavior of the inter-bursting-intervals of the neurons, what we call neuron variability, to the ability of the network to depict anomalous phase synchronization. We corroborate the ideas showing that ambient parameter changes eliminate anomalous phase synchronization, at the same time promote small changes in the individual dynamics of the neurons such that an increasing individual variability of neurons implies in a decreasing of anomalous phase synchronization.

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27 Nov
2:00pm
Room 6

Networks as competing entities

Javier M. Buldú[1], Jaime Iranzo[2], Jacobo Aguirre[3]

[1]Universidad Rey Juan Carlos, Spain; [2]National Center for Biotechnology Information, USA; [3]Centro Nacional de Biotecnología, Spain

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 investigate 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. With this objective in mind, we define a methodology to analyse the competition among networks of any size or topology, demonstrating that several Nash equilibria can coexist, with some of them benefiting the strongest networks and others benefiting the weaker ones. Particularly, we report the existence of a wide regime of the system parameters in which every weak network can induce the rest to cooperate in order to escape from a detrimental Nash equilibrium, taking over the final situation of the whole network-of-networks.

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27 Nov
2:30am
Room 6

Graph Matching: deterministic and probabilistic results

Marcelo Fiori

Universidad de la Repblica, Uruguay

Graph matching –aligning a pair of graphs to minimize their edge disagreements– has received wide-spread attention from both theoretical and applied communities over the past several decades, including combinatorics, computer vision, and biomedical problems. Its attention can be partially attributed to its computational difficulty. Although many heuristics have previously been proposed in the literature to approximately solve graph matching, very few have any theoretical support for their performance. A common technique is to relax the discrete problem to a continuous problem, therefore enabling gradient-descent-type algorithms.

In this talk we will present deterministic and probabilistic results. First, we show that the graph matching problem and its most common convex relaxation,

where the matching domain of permutation matrices is substituted with its convex hull of doubly-stochastic matrices, are equivalent for a certain class of graphs, such equivalence being based on spectral properties of the corresponding adjacency matrices. We also derive results about the automorphism group of a graph, and provide fundamental spectral properties of the adjacency matrix.

Then, new probabilistic results about convex and non-convex relaxations of the graph matching problem will be discussed, also suggesting some practical considerations. We prove that an indefinite relaxation (when solved exactly) almost always discovers the optimal permutation, while the common convex relaxation almost always fails to discover the optimal permutation. These theoretical results suggest that initializing the indefinite algorithm with the convex optimum might yield improved practical performance. Indeed, experimental results illuminate and corroborate these theoretical findings, demonstrating that excellent results are achieved in both benchmark and real data problems by amalgamating the two approaches.

Asymmetric cluster and chimera dynamics in globally coupled systems

27 Nov
4:15pm
Room 4

A. V. Cano and M. G. Cosenza

Universidad de Los Andes, Mérida, Venezuela

We investigate the emergence of chimera and cluster states possessing asymmetric dynamics in globally coupled systems, where the trajectories of oscillators belonging to different subpopulations exhibit different dynamical properties. In an asymmetric chimera state, the trajectory of an element in the synchronized subset is stationary or periodic, while that of an oscillator in the desynchronized subset is chaotic. In an asymmetric cluster state, the periods of the trajectories of elements belonging to different clusters are different. We consider a network of globally coupled chaotic maps as a simple model for the occurrence of such asymmetric states in spatiotemporal systems. We employ the analogy between a single map subject to a constant drive and the effective local dynamics in the globally coupled map system to elucidate the mechanisms for the emergence of asymmetric chimera and cluster states in the latter system. By obtaining the dynamical responses of the driven map, we establish a condition for the equivalence of the dynamics of the driven map and that of the system of globally coupled maps. This condition is applied to predict parameter values and subset partitions for the formation of asymmetric cluster and chimera states in the globally coupled system.

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27 Nov
4:15pm
Room 6

Control optimization of the vibro-impact capsule system

Marek Balcerzak and Andrzej Stefanski
Lodz University of Technology, Poland.

Vibro-impact capsule system is a novel type of propulsion that utilizes an internal impact oscillator. Motion of the system is caused only by an action of inertia forces and friction forces. Therefore, the capsule does not require any external moving parts, such as wheels, continuous tracks or robotic legs to go. Energy is delivered to the system by an external forcing of the oscillator, which can be realized contactlessly, for example via electromagnetic forces. Dynamics of such system with a sinusoidal forcing has already been investigated. However, a question arises: what kind of external forcing should be applied in order to obtain maximum average speed of the drive ? Typically, such problems are solved using optimal control theory. In particular, necessary conditions for the optimal control can be obtained by means of the Pontryagin's maximum principle (PMP) as long as the system under consideration is smooth. However, the vibro-impact capsule system is non-smooth due to presence of the impact oscillator. Moreover, a dry friction discontinuity has to be taken into account. Therefore, different methods must be applied. In this work, authors propose to use two approximate methods simultaneously. Firstly, approximate dynamics of the system is described by means of continuous functions. Then, the PMP is applied for such approximate equations. Secondly, control function of the discontinuous, non-smooth system is defined in terms of the Fourier series. Constants connected with subsequent terms of the series are optimized numerically. Results show that both approaches result in a bang-bang control with appropriate proportions of extreme signal values. Outcomes of this study can be applied to control the vibro-impact capsule system in such a way, that maximal possible speed is obtained. They can also be generalized and applied in other non-smooth systems, where control optimization is necessary.

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27 Nov
4:45pm
Room 4

Coherent libration to coherent rotational dynamics via chimeralike states and clustering in a Josephson junction array

Arindam Mishra[1], Suman Saha[1], Chittaranjan Hens[2], Prodyot K. Roy[3], Mridul Bose[1], Patrick Louodop[4], Hilda A. Cerdeira[5], Syamal K. Dana[1]
[1]Jadavpur University, India; [2]Indian Statistical Institute, India; [3]Presidency University, India; [4]University of Dschang, Cameroon; [5]Universidade Estadual Paulista, Brazil

An array of excitable Josephson junctions under a global mean-field interaction and a common periodic forcing shows the emergence of two important classes of coherent dynamics, librational and rotational motion, in the weaker and stronger coupling limits, respectively, with transitions to chimeralike states and clustered states in the intermediate coupling range. In cylindrical space, the trajectory of a junction is localized during a libration while it encircles the cylinder during a rotational motion. Most importantly, we observe a transition between the two coherent

states for changing coupling interactions. When increasing the coupling strength from a weaker range, the coherent librational motion emerges above a threshold and continues for a range of coupling, then transits to coherent rotational motion for large coupling via successive chimeralike states and clustered states in an intermediate coupling range. In the chimeralike states, we notice the coexistence of regular librational motion in a coherent subpopulation and chaotic rotational motion in another noncoherent subpopulation. In the clustered state, regular libration coexists with rotational motion in two subpopulations.

To distinguish the emergent states and their dynamics, we use the complex Kuramoto order parameter (r) and introduce two measures, a clustering index (s) and a libration index (l). The Kuramoto order parameter tells us about emergence of a coherent state or synchronization ($r = 1$), complete disordered state or incoherent state ($r = 0$ in the thermodynamic limit) and about the partially synchronized states ($0 < r < 1$) with varying coupling interaction between an ensemble of oscillators. However, it can not distinguish between the chimera and cluster states when the value of the order parameter could be $0 < r < 1$ for both the states. It tells us nothing about the dynamics of the system. In our study, we distinguish different collective behaviors by defining two new measures namely, a libration index (l) and cluster index (s) besides the complex Kuramoto order parameter(r). The libration index (l) especially distinguish the collective dynamics of the ensemble of the junctions, the libration motion and the rotational motion and the cluster index (s) distinguish between chimera and cluster states.

Chaotic synchronization of damped parametric pendulums

27 Nov
4:45pm
Room 6

Andrzej Stefanski and Marek Balcerzak

Lodz University of Technology, Poland.

In this paper a multi degree of freedom mechanical system composed of a set of damped pendulums attached to common driven structure, oscillating in vertical direction, is investigated. One can observe that the application of such transitional stage (structure) allows to chaos synchronization of parametrically driven pendulums. Presented analysis is focused on the chaotic synchronization of swinging (not rotating) identical pendulums. However, it is shown that such a phenomenon is possible even in case of slight differences between swinging system. In the presence of parameters mismatch, chaotic synchronous behavior exhibits the features of intermittency between two opposing solutions. This phenomenon manifests with alternately occurring in phase and in antiphase synchronous states (intermittent phase – antiphase synchronization). The criterion of synchronization for any number of pendulums is proposed. This idea is based on the classical concept of autonomous driver decomposition of the dynamical system (Pecora and Carroll, 1990) and application of so-called conditional Lyapunov exponents.

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29 Nov
11:00am
Room 5

A stochastic nonlinear dynamic model for Zika virus outbreak in Brazil

Americo Cunha Jr, Eber Dantas and Michel Tosin
Universidade do Estado do Rio de Janeiro, Brazil.

Several instances of Zika virus epidemic have been reported around the world in the last 20 years, causing Zika fever to become a disease of international concern. This work deals with the adaptation of a compartmental epidemic model to predict the evolution of Zika virus in Brazilian scenario and the posterior calibration of this predictive tool with respect to real data, from the recent outbreak of the disease, by solving an inverse problem. Model parameters variabilities are taken into account through parametric probabilistic approach, that employs an information-theoretic formalism (maximum entropy principle) to construct a consistent stochastic model and use Monte Carlo simulation for propagate the uncertainties. This development gives rise to a realistic epidemic model capable of making robust predictions about epidemic scenarios.

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29 Nov
11:00am
Room 6

Role of the range of the interactions in heat transport

Celia Anteneodo[1] and Carlos Olivares[2]
[1]Pontifícia Universidade Católica do Rio de Janeiro, Brazil; [2]Universidade Federal Fluminense, Brazil.

Heat conduction is usually described by the Fouriers law, however this law fails in many one-dimensional systems, where the temperature profile and the conductivity are anomalous. These anomalies depend on the type of interactions between the elements that compose the system. On the other hand, it is well known that the range of the interactions changes considerably the dynamic and thermodynamic properties of a system, emerging features such as negative specific heat, quasi-stationary states, ergodicity breaking and ensemble inequivalence. This scenario motivates the study of the effects of the range of interactions in the context of heat transport. We consider a paradigmatic Hamiltonian system known in the literature as α-XY model, which consists of a one-dimensional lattice of classical rotators with attractive couplings that decrease with distance as a power law, with exponent α, allowing to scan from nearest-neighbors to infinite range interactions. The ends of the chain are put in contact with Brownian heat reservoirs at different temperatures with mean value T. By means of numerical integration of the Hamiltonian equations of motion, we show the effects of the range of the interactions in the temperature profile and energy flux, determining the domain of validity of Fourier's law in this context. We find that Fourier's law holds only for sufficiently short range interactions, while a kind of insulator behavior appears for global interactions. For intermediate ranges, we establish different regimes for the behavior of the conductivity with system size, depending on α and the average temperature T.

Influence of rainfall variability on the resilience of the Amazon rainforest

29 Nov
11:00am
Aula Magistral

Catrin Ciemer

Potsdam Institut of Climate Impact Research, Germany.

Hydrological extremes have severe impacts in tropical South America and the Amazon basin in particular. Droughts increase the risk of fires and extreme heat waves, whereas prolonged episodes of enhanced rainfall can lead to devastating floods. Both have severe effects on the flora and fauna. It is projected that the frequency of hydrological extremes will increase in the near future. We thus investigate the long-term influence of rainfall variability on tree cover to estimate if the rainforest is able to adapt to those changes.

Spatio-temporal intermittent intervention in social and dynamical systems

29 Nov
11:30am
Room 5

Jose Luis Herrera Diestra

South American Institute for Fundamental Research, Brazil.

Interventions in extended chaotic systems, where an external or autonomous field influences a system for it to achieve a determined state, have been the target of several research. For instance, Alvarez-Llamoza and Cosenza (O. Alvarez-Llamoza, M.G. Cosenza International Journal of Bifurcations and Chaos, 20, 323, (2010)) considered different extension of this problem by applying intermittent external drivers to a given fraction of randomly chosen elements in a system with given frequencies. In these approach, the elements could interact with any other elements - no notion of locality was introduced. More recently, the conditions for global synchronization of Kuramoto oscillators on networks where only a fraction of them is subjected to a periodic external force was studied by Moreira and Aguiar (Global synchronization of partially forced Kuramoto oscillators on Networks CA Moreira, MAM de Aguiar arXiv preprint arXiv:1802.07691). In the examples above, the objective is the search for the minimal requirements for the emergence of synchronization in dynamical systems. In these order of ideas, we extend the quest for the minimal ingredients (topological and dynamical) that drive a system into a desired state; particularly, synchronous. We explore spatio-temporal intermittent interventions in diverse systems where the notion of locality (complex networks) is taken into account. Specifically, spatio-temporal intermittent interventions refers to the systematic characterization of the macroscopic state of a system when influenced: a) always; b) at given times; with a c) external or d) autonomous field. This field can be computed/applied with/to e) the whole system; d) a particular fraction of the nodes. The potential application for this research include epidemiology (surveillance, vaccination), social sciences (mass-media), power grids (failure control), among others.

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29 Nov
11:30am
Room 6

Diffusion and reaction-diffusion processes in growing domains

Enrique Abad[1], Carlos Escudero[2], Felipe Le Vot[1] and Santos B. Yuste[1]

[1]Universidad de Extremadura, Spain; [2]Universidad Autónoma de Madrid, Spain.

Most studies devoted to diffusion assume that it takes place in a static domain. However, dynamic domains are an important paradigm in biology and cosmology, since the domain growth or contraction may compete with diffusive transport on a similar time scale. For instance, in developmental biology, the formation of biological structures (e.g. the pigmentation of skin) occurs during tissue growth. Another example is the diffusion of cosmic rays in the expanding universe. In this contribution, we review some of our own recent results for diffusion processes taking place in deterministically growing/contracting domains. For a uniform domain growth dictated by a power-law, we find striking crossover effects allowing one to distinguish between a diffusion-controlled regime and another regime where the domain growth becomes the dominant transport mechanism. In the latter case, we find a strong memory of the initial condition resulting from the limitations placed by the growth process on diffusional mixing. Another striking effect is the fact that diffusive particle spreading is counterbalanced by an exponential contraction of the domain, resulting in the onset of a stationary propagator (this effect is destroyed as soon as the diffusion process is replaced by a subdiffusive Continuous Time Random Walk). Finally, we discuss some examples of first-passage processes related to the notion of survival probability, i.e., the escape of a Brownian walker from a growing hypersphere, “the target problem”, and the kinetics of the coalescence reaction $A + A \to A$. In the latter example, the self-ordering process induced by the encounter-controlled chemical reactions is frustrated prematurely by a sufficiently fast domain growth. The obtained results highlight the need to extend the existing first-passage theories of chemical kinetics to deal with the interplay between diffusional mixing and the effect of the domain growth. Possible implications of the above findings for real systems will be discussed.

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29 Nov
11:30am
Aula Magistral

Irradiance drops induced by turbulence as extreme events

Felipe Olivares[1], Gustavo Funes[2] and Dario G. Pérez[1]

[1]Pontificia Universidad Católica de Valparaíso, Chile; [2]Universidad de Los Andes, Chile.

Free-space optical communication links through the atmosphere are degraded mainly by the action of scintillation and beam wander. Both phenomena are responsible for fiber coupling misalignments at the receiver. While irradiance scintillation can be diminished by aperture averaging, wandering induced scintillation will remain unmitigated, yielding high power at the detector with sparse random power drops, identified as extreme events. The statistics of return intervals, defined as the time difference between two consecutive extreme events, is a powerful tool to characterize the (temporal) scaling properties of the original time series [J. F. Eichner, J. W. Kantelhardt, A. Bunde, and S. Havlin, Phys. Rev. E 75, 011128 (2007).]. In this work we present the first experimental work (to our knowledge) by characterizing the temporal properties of the return intervals extracted from irradiance fluctuations as a result of a beam propagating through controlled convective turbulence. We confirm that the return intervals inherit the scaling properties from the original irradiance time series. Moreover, we are able to confirm that the anisotropy of the convective turbulence is expressed through different scaling exponents between the horizontal and vertical centroid fluctuations, previously reported by us [G. Funes, F. Olivares, C. Weinberger, Y. Carrasco, L. Nuñez and D. G. Pérez, Opt. Lett. 41, 5696 (2016)]. In addition, a numerical simulation based on fBm stochastic processes, allows us to conclude that beam wander is basically the only contributor to pointing error and the creation of extreme events in intensity time series obtained from fiber coupling.

Spontaneous emergence of a third position in an opinion formation model

29 Nov
12:00pm
Room 5

Marcos Gaudiano and Jorge Revelli

Universidad Nacional de Córdoba, Argentina

Opinion dynamics is one of the most studied problems in sociophysics. Many easy-to-analyze dynamical systems are modelled in a language of agent-based numerical procedures in order to provide new insights for understanding collective phenomena.

The present work is devoted to analyze the effects of spatial heterogeneties in the initial topological map of agent ideas. In the spirit of the statistical physics of social impact, we study the consequences of running a Sznajd model into a structured opinion formation dynamics of a given social community. We carry out a spatio-temporal fractal analysis of the ideological configuration map, showing novel features belonging to different initial conditions. By performing numerical simulations, we mainly show how the evolution of ideas can lead to a spontaneous emergence of a third ideological position. This emergence is just characterized by few parameters: the dimensionality of the initial ideological structures and the interaction dynamics. No additional external constraints are assumed. Moreover, the third position presents a non-monotonus dependence with the system fractality.

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29 Nov
12:00pm
Room 6

Colloids and polymers in flickering confinements

María Florencia Carusela[1], J. Miguel Rubi[2] and Paolo Malgaretti[3]

[1]Universidad Nacional de General Sarmiento, Argentina; [2]Universitat de Barcelona, Spain, [3]Max Planck Insitute for Intelligent Systems, Germany

We study the current rectification of colloids across a narrow pulsating channel and under the action of a constant external force (eg an E-field or a pressuregradient). We find different rectification scenarios due to entropic and energetic contributions. The effect can be quantified by means of a rectification coefficient as a function of the force, the diffusion coefficient and the frequency. We also study the translocation of polymers across the same type of confinements, using a simplified model that reduces the problem of polymer translocation through varying-section channels to that of a point-like particle under the action of an effective potential. With such a model we can identify the relevant parameters controlling the polymer dynamics for Gaussian and self-avoiding polymers in three-dimensional confinements. On the other hand, in both systems we analyze the rectification phenomena under the prism of dissipation. We study the energetic cost of the rectification mechanism by computing the entropy production from the knowledge of the particle current and the effective force. Rectification is more important at low values of the applied force when entropic effects become dominant. In this regime, the entropy production is not invariant under reversal of the applied force and current reversal occurs. We discuss how the phenomenon observed could be used to optimize transport in microfluidic devices or in biological channels.

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29 Nov
12:00pm
Aula Magistral

ENSO teleconnections in the southern hemisphere: A climate network view

Fernando Arizmendi and Marcelo Barreiro

Universidad de la República, Uruguay.

Using functional network analysis we study the seasonality of atmospheric connectivity as well as its interannual variability depending on the different phases of El Niño-Southern Oscillation (ENSO) phenomenon. We find a strong variability of the connectivity on seasonal and interannual time scales both in the tropical and extratropical regions. In particular, there are significant changes in the southern hemisphere extratropical atmospheric connectivity during austral spring within the different stages of ENSO: We find that the connectivity patterns due to stationary Rossby waves differ during El Niño and La Niña, showing a very clear wave train originating close to Australia in the former case, as opposed to La Niña that seems to generate a wave train from the central Pacific. An attempt to understand these differences in terms of changes in the frequency of intraseasonal weather regimes cannot fully explain the differences in connectivity, even though we found prevalence of different intraseasonal regimes in each phase of ENSO. We conclude that the differential response to extreme phases of ENSO during austral springtime is related to the forcing of waves of different tropical origins.

Dynamic acousto-elasticity: Characterizing Rocks as a nonlinear system

29 Nov
2:00pm
Room 6

Thomas Gallot[1] and Alison Malcolm[2]

[1]Universidad de la República, Uruguay; [2]University of Newfoundland, Canada.

In rocks, nonlinear elasticity vary over several orders of magnitude. Measuring this information is a challenging research area for several geophysics questions such as earthquake source physics, or reservoir fracturation process. These methods generally relies on vibrating a sample at a fixed resonant frequency to create a low frequency strain (the pump). The need of high amplitude standing wave restrains the possibility of a localized estimation of the nonlinearity. To overcome this limitation, the proposed method is based on propagative waves. A laboratory scale experiment have been performed in rocks. A sample of berea sandstone is probed with a low amplitude-high frequency pressure wave. The probe interacts nonlinearly with a high amplitude-low frequency shear wave, on the order of 10^{-6} in strain. The resulting time of flight modulation coupled with strain estimation from laser particle velocitmetry, allows to measure quadratic and cubic nonlinear parameters, $\beta = -872$ and $\delta = 1.1 \times 10^{-10}$ respectively. Temperature fluctuations are correlated to changes in the recovered nonlinearity. No evidence of slow dynamics was seen in our measurements. Preliminary results shows localization of nonlinear perturbation.

Evolution of instabilities in buckling processes

29 Nov
2:30pm
Room 6

Alejandro Gabriel Monastra[1], María Florencia Carusela[1], Guido van der Velde[2], Mara Vernica D'Angelo[2], Luciana Bruno[2]

[1]Universidad Nacional de Gral. Sarmiento, Argentina; [2]Universidad Nacional de Buenos Aires, Argentina

Buckling of semi-flexible filaments appears in different systems and scales. Some examples are: fibers in geophysical applications, microtubules in the cytoplasm of eukaryotic cells, and deformation of polymers freely suspended in a flow. In these examples, instabilities arise when some parameters exceed a critical value, being the Euler critical force the most known. However, the complete time evolution and wavelength of buckling processes is not fully understood. In this work we make a theoretical, simulational and experimental approach to the problem. We first solve analytically the time evolution equation of a semi-flexible filament in a pure viscous medium, under a constant compressive force, in the small amplitude approximation. We obtain solutions which grow exponentially in time and whose shapes depends parametrically on the compressing force, which also determines a characteristic effective wave number. Secondly, we perform finite element numerical simulations of the filament for the scenario of a constant speed of compression, obtaining the instantaneous compressing force. This allows us to connect the simulations with the analytical results, comparing the obtained wave numbers. The evolution is highly sensitive to the initial configuration and to the velocity of compression, although the obtained wave numbers are comparable. Finally, we compare the numerical simulations with experiments of compression of polyethylene terephthalate filaments immersed in glycerol, obtaining a very good agreement in shapes, time scale and wave numbers, at slow and fast speeds of compression.

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29 Nov
4:15pm
Room 6

Three dimensional convection in autocatalytic reaction fronts

Desiderio Vásquez, Pablo Vilela and Johan Llamoza
Pontificia Universidad Católica del Perú, Peru.

The propagation of autocatalytic reaction fronts can be modeled with front evolution equations such as the Kardar-Parisi-Zhang (KPZ) equation or the Kuramoto-Sivashinsky (KS) equation. These types of equation assume a thin interface separating reacted from unreacted fluids. The KPZ equation has a stable flat front solution in non-moving media. In the case of the KS equation, we can find flat front or curved fronts propagating with constant velocity inside a tube. The fronts can also exhibit complex spatio-temporal behavior as the diameter of the tube increases. Reaction fronts propagating in liquids intereact with fluid motion thus modifying the behavior of the fronts. This fluid motion can be caused by changes in density across the front, or by an abrupt change in surface tension. In this work, we explore the interaction of fluid motion with the propagating front. We show that the presence of density gradients can inhibit or enhance front instabilities depending on the direction of the gradient. We show that the presence of fluid motion can lead to oscillatory instablities, that cannot be obtained without flow. In the case of surface tension driven flow, the front speed is enhanced even if the surface flow is against the direction of propagation. Three dimensional calculations in tubes of rectangular cross section show steady fronts of different shapes and speeds. We find steady solutions of the equations determining the stability of the solutions. We find bifurcations between them and regions of bistability.

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29 Nov
4:45pm
Room 6

Topological transitions in driven systems

Marcel Clerc
Universidad de Chile, Chile

Matter in thermodynamic equilibrium, in almost two spatial dimensions, decreasing the temperature can exhibit topological transitions associated with the emergence of pairs of vortices (transition from Berezinskii-Kosterlitz-Thouless). This type of phenomenon has been observed in diverse contexts such as Josephson junctures, superconducting films, among others. Which allowed obtaining the Nobel to Kosterlitz-Thouless 2016. In this presentation, theoretically, we will show a generalization of this phenomenon for out of equilibrium systems?systems with temporarily modulated parameters. Experimentally, we will verify this phenomenon employing the emergence of pairs of defects umbilics in a liquid crystal film subjected to an oscillating voltage.

Swimming along a fixed direction in steady flows: constant versus periodically modulated self-propulsion velocity

30 Nov
11:00am
Room 5

Alfredo Manuel Jara Grados and Rafael Ribeiro Dias Vilela de Oliveira

Universidade Federal do ABC, Brazil.

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. In both models the self-propulsion velocity of the particles is, at any instant, along the predetermined direction. The first model corresponds to self propulsion with constant speed and the second model corresponds to self-propulsion with a sinusoidal temporal modulation of the speed. 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 which do not remain confined in a bounded region of the physical space? We use numerical and analytical methods to address this question.

Basin of synchronization in the Kuramoto model by eigenvalues of twist states.

30 Nov
11:00am
Aula Magna

Antonio Mihara and Rene Orlando Medrano Torricos

Universidade Federal de São Paulo, Brazil.

Twist states are synchronized states in the Kuramoto model (with identical oscillators equally coupled) where the difference between the phase of consecutive oscillators is always the same. We study the relation between the basin of attraction and the eigenvalues of stable twist states and show the unexpected result: the global statical and size properties of these basins follow the local action of the eigenvalues of all possible stable synchronized states. Numerical and analytical approaches are presented to support our result.

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30 Nov
11:00pm
Room 6

Critical slowing down as indicator of bifurcations

Jorge R. Tredicce[1,2], C. Metayer[1], Jean M. Boyer[1], and A. Gomel[2]
[1]Universite de la Nouvelle Caledonie, New Caledonia; [2]Universidad de Buenos Aires, Argentina;

There was always a special interest in trying to predict transitions, crisis, social revolutions, catastrophic events like the end of the world and, nowadays judging by the number of spam messages coming from clairvoyants, we strongly believe that the interest in predicting events of every type is growing fast. We can positively say that there is an increasing scientific interest in determining the good indicators that may anticipate a dramatic change in the behavior of a dynamical system, also called a bifurcation, which in some cases may be at the origin of a catastrophe. It has been conjectured that the advent of an epilepsy attack is the result of a phase transition; that climate in earth is actually very close to a bifurcation point ; that extremely intense pulses in lasers may result from a bifurcation of a chaotic attractor; and that evolutive specialization in ecology is also the consequence of a bifurcation. We could mention many different events of general interest which are examples associated to the existence of a bifurcation in a nonlinear system. Actually the idea of predicting an extreme event is based on the existence of some indicators that may tell us if we are approaching a bifurcation point or a tipping point. The unambiguous indicator is related to a common property of bifurcations: the critical slowing down. Here we studied numerically a nonlinear dynamical system possessing a transcritical bifurcation at some control parameter value. We studied the relaxation time of the variables when the control parameter is swept across the bifurcation point. We show that depending on the sweep velocity and the dissipation of the system, the effects of the critical slowing down may be delayed and therefore they may appear after the bifurcation already took place.

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30 Nov
11:30am
Room 5

Bifurcation approach to the the Square-Hills Equation: application to the Kronig-Penney model

Jorge Galan-Vioque, Emilio Freire and Manuel Ordoñez
University of Seville, Spain.

Hills equation has been extensively studied in the literature and has many application in dynamical systems. The periodic piecewise case has received less interest although we will show that it can been analytically solved by explicitly computing the monodromy matrix. We will study the bifurcation behaviour structure as the parameters are varied identifying the regions of higher co-dimension. We will illustrate the power of this approach with the well known Kronig Penney model for band formation in periodic structures.

Dragon-king-like extreme events in coupled bursting neurons

30 Nov
11:30am
Aula Magna

Tomasz Kapitaniak

Lodz University of Technology

We present evidence of extreme events in two Hindmarsh-Rose (HR) bursting neurons mutually interacting via two different coupling configurations: chemical synaptic and gap junctional type diffusive coupling. A dragon-king-like probability distribution of the extreme events is seen for combinations of synaptic coupling where small to medium size events obey a power law and the larger events that cross an extreme limit are outliers. The extreme events originate due to instability in anti-phase synchronization (APS) of the coupled systems via two different routes, intermittency and quasiperiodicity routes to complex dynamics for purely excitatory and inhibitory chemical synaptic coupling, respectively. For a mixed type of inhibitory and excitatory chemical synaptic interactions, the intermittency route to extreme events is only seen. Extreme events with our suggested distribution is also seen for gap junctional type diffusive, but repulsive coupling where the intermittency route to complexity is found. A simple electronic experiment using two diffusively coupled analog circuits of the HR neuron model, but interacting in a repulsive way, confirms occurrence of the dragon-king-like extreme events.

Long-tail statistics in semiconductor lasers with double feedback

30 Nov
11:30am
Room 6

Wendson Barbosa[1], Edison Rosero[1], Jorge Tredicce[2] and Jose Rios Leite[1]

[1]Universidade Federal de Pernambuco, Brazil; [2]Universite de la Nouvelle Caledonie, New Caledonia.

We demonstrate experimental and theoretically how a semiconductor laser subjected to double optical feedback modifies its power fluctuating dynamics from chaos with Gaussian statistics to chaos with heavy tail Levy distributions pulse bursting and to stationary behavior as the proportion between the two time delays is varied. The long-tail distributions for the time interval between power drops occur according to the ratio of time delays in the neighborhood of the Farey sequence. Numerical solutions of the deterministic rate equations system, generalized from the Lang-Kobayashi model, fits the observed dynamics and its statistics.

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30 Nov
12:00pm
Room 5

On demand generation of privately shared pseudo-random bit sequences using chaos

Hugo Leonardo Davi de Souza Cavalcante[1] and Gilson Francisco de Oliveira-Jr.[2]

[1]Universidade Federal da Paraíba, Brazil; [2]Universidade Federal do Cariri, Brazil

In the phenomenon of attractor bubbling, a pair of chaotic systems fail to remain synchronized even when subject to a strong coupling term. We explore this phenomenon to produce a sequence of pseudo-random bits that can be shared with a private party while communicating only through a public channel. The sequence is generated by a transmitter subsystem, comprised of one master chaotic oscillator and two slave oscillators set in the attractor bubbling regime. In order to share the sequence with a communicating party, only the signal of the master oscillator is transmitted over a public channel to the receiver end, where a high-quality synchronization recovers the state of the master oscillator and uses it as a proxy to reproduce the coupling between the two local copies of the slave oscillators in the receiver subsystem. The privacy of the technique resides on the fact that only the information about the master oscillator state is transmitted over the public channel, while the parameters of the slave oscillator systems are shared previously over a private channel. These parameters function as the key-code for the communicating protocol. Once the master oscillators synchronize, the slave oscillators on each end will also synchronize to their respective counterpart, and thus one can reproduce the same sequence of pseudo-random bits on each side of the communication channel, for arbitrarily long time. A small error rate caused by imperfections in the recovered states can be mitigated by using redundancy or error correcting codes.

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30 Nov
12:00pm
Aula Magna

Amplitude turbulence induced extreme event in Kerr cavities

Saliya Coulibaly[1], Abdelmajid Taki[1], Abdelkrim Bendahmane[2], Guy Millot[2], Bertrand Kibler[2] and Marcel G. Clerc[3]

[1]Université de Lille, France; [2]Université Bourgonge Franche-Comté, France; [3]Universidad de Chile, Chile

Nonlinear driven resonators such as lasers cavities, water channels, superconducting qubits, nanoelectromechanical membranes, spin valves nanopillars, Josephson junctions are widely studied for their complex dynamics and transitions among them. Here, we study the emergence of complexity from standing waves. We follow the evolution of these patterns from the weak to the unexplored large driving strength regime. We have successively identified and characterized oscillatory bifurcation, spatiotemporal chaos via spatiotemporal intermittency, and fully developed turbulence. Based on a fiber ring resonator, the predicted universal scenario is observed and confirmed. Light bursts in the resulting turbulent regime reveal extreme events dynamics.

Tricorn-like structures in an optically injected semiconductor laser

30 Nov
12:00pm
Room 6

C. Abraham T. Chavez[1,2], I. L. Caldas[3]

[1]Universidade Federal do Rio Grande do Sul, Brazil; [2]Universidad Mayor de San Simón, Bolivia;[3]Universidade de São Paulo, Brazil.

In this work we report the existence of *tricorn*-like structures of stable periodic orbits in the parameter plane of an optically injected semiconductor laser model (a continuous time dynamical system). These *tricorns* appear inside *tongue*-like structures that born through simple Shi'lnikov bifurcations. As we increase the *linewidth enhancement factor*-α of the laser, these *tongues* invade the locking zone of the laser and extends over the zone of stable orbits of period-1. This invasion provocates a rich dynamic of overlap of parameter planes that produce an abundant multistability. As we increase α the *tricorn* also exhibits a phenomenon of codimension-3 rotating in clock and anti-clockwise in the plane of the injected field rate K vs. its detunning ω. We hope that the numerical evidence of the existence of *tricorns* that we present here motivates the study of mathematical conditions for their genesis. And also we encourage the experimental verification of these *tricorn*-like structures because our results also open new possibilities for optical switching between several different outputs of the laser in the neighbourhood of these structures.

Combining random searches, individual's memory, and population dynamics: analysis of population redistribution patterns

30 Nov
2:00pm
Room 5

Juliana M. Berbert and Karen A. Oliveira

Federal University of ABC, Brazil

One of the possible ways for modeling animal movement is using the reaction-diffusion equation, in which the reactive part stands for the population growth and the diffusive part for random dispersal of the population. However, there are some mechanisms that affect the movement decisions, such as landscape persistence, resource depletion or individual's spatial memory of recently depleted patches. The former one results in a bias for one direction of dispersal and can be modeled by an advective term on an advection-reaction-diffusion equation. Therefore, we propose a model composed of a coupled nonlinear partial differential equation system with one equation for the movement and population dynamics and other for the individual's spatial memory density distribution. For the population growth, we use either the exponential or logistic growth function. The analytic approach has shown that for the exponential and logistic growth the traveling wave speeds are the same with or without memory dynamics. From the numerical analysis, we have explored how the population redistribution is affected by different values of the parameters: individual's memory, growth rate, and carrying capacity. Combining these parameters results on a redistribution pattern of the population associated to either normal or (smooth) super diffusion.

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30 Nov
2:00pm
Aula Magna

Recurrence entropy quantification of time series

Sergio Lopes[1], Thiago Prado[2], Gilberto Corso[2] and Gustavo Lima[3]

[1]Federal University of Parana; [2]Federal University of Jequitinhonha and Mucuri Valeys Federal [3]University of Rio Grande do Norte

We conceive a new recurrence quantifier for time series based on the concept of information entropy, in which the probabilities are associated to the presence of microstates defined on the recurrence matrix as small binary (sub)matrices. The new methodology to compute the entropy of a time series has advantages compared to the traditional entropies defined in the literature, namely, a good correlation with the maximum Lyapunov exponent of the system and a weak dependence on the vicinity threshold parameter. Furthermore, the new method works adequately even for small segments of data, bringing consistent results for short and long time series. In a case where long time series are available, the new methodology can be employed to obtain high precision results since it does not demand large computational times related to the analysis of the entire time series or recurrence matrices, as is the case of other traditional entropy quantifiers. The method is applied to discrete and continuous systems.

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30 Nov
2:00pm
Room 6

Nonstationary transition to phase synchronization of neural networks induced by the coupling architecture

Roberto C. Budzinski[1], Bruno Rafael Reichert Boaretto[1], Thiago De Lima Prado[2] and Sergio R. Lopes[1]

[1]Universidade Federal do Paraná, Brazil; [2]Universidade Federal dos Vales do Jequitinhonha e Mucuri, Brazil.

Through the complex networks and mathematical modeling, is it possible to investigate dynamical properties of neural systems. It is known that the transition to phase synchronized states of neural networks with bursting dynamics may present nonstationary characteristics, as well as, sensitivity to initial conditions. In this way, it is analyzed a network composed of neurons of Rulkov to investigate dynamic properties of the transitions to phase synchronization displayed by neural systems under two different topologies of the connection architecture, the small-world and the random ones. The analyses of both connection architectures reveal that neural networks under small-world topology can display higher sensibility to initial conditions, and, contrarily to the random connection case, depict a nonstationary transition to phase synchronization through the presence of a two-state on-off intermittency. The analyses are based on the recurrence quantification analyses, particularly, the determinism calculated from data of the local (mean) field potential (LFP) of the network, an experimentally easy accessible data. The use of LFP data offers advantages in the quantification of the nonstationary dynamics at the transition to phase synchronized states, since the more traditional Kuramoto order parameter must be computed over the individual signals of the neurons.

A dynamical model to explain outbreaks of Hantavirus infections

30 Nov
2:30pm
Room 5

Marita S. Torre[1], Jean M. Boyer[2], and Jorge Tredicce[2,3]

[1]Universidad Nacional del Centro de la Provincia de Buenos Aires, Argentina; [2]Universite de la Nouvelle Caledonie, New Caledonia; [3]Universidad de Buenos Aires, Argentina.

Simple models for population dynamics have been used in the past to study outbreaks of infections. Usually the ecological conditions were considered as parameters remaining constant in time. Here we analyze the propagation of a virus when the ecological conditions change slowly in time. In particular we consider a model used to simulate the propagation of Hanta virus in the mice population. We show that a changing parameter varying much slower than the time constants associated with the variables may cause a much faster increase in the density of infected mice generating an epidemic of hanta virus. Thus, the ecological process with very long periodical cycle or with low frequency of occurrence, such us the colihue bamboo (Chusquea culeou) bloom, increases the mice density and it may produce an outbreaks of the disease . The results obtained also agree with other experimental observations, such as the disappearance of the infection for prolonged periods and its abrupt appearance. This later phenomenon is explained in terms of the critical slowing down resulting from crossing a bifurcation point. We also studied how the variations in time of the parameters induce a chaotic behavior of the variables.

Maximum entropy of recurrence microstates

30 Nov
2:30pm
Aula Magna

Thiago De Lima Prado[1], Gilberto Corso[2], Gustavo Zampier Dos Santos Lima[2], Roberto Cesar Budzinski[3], Bruno Rafael Reichert Boaretto[3] and Sergio Roberto Lopes[3]

[1]Universidade Federal dos Vales do Jequitinhonha e Mucuri, Brazil; [2]Universidade Federal do Rio Grande do Norte, Brazil;[3]Universidade Federal do Paraná, Brazil

Dynamical recurrences are natural process which are widespread in nature, occurring in precipitation data, earthquakes, volcano eruptions and human activities, such as market oscillations or economic crises. One of the main conceptions of recurrences is described by Henri Poincar in late 19th century, in a seminal work aimed to evaluate the three body problem. More recently Eckmann at all. translated Poincar concept in a visual tool known as Recurrence Plot (RPs), which mainly uses a fixed threshold to evaluate distance in phase space from dynamical trajectories, where the states on a trajectory is recurrent (one) or non-recurrent (zero). Several techniques were developed to quantify RPs structures, these are known as Recurrence Quantification Analysis (RQAs), and it typically evaluate (non)recurrence density, diagonal and vertical/horizontal lines statistics, or in the perspective of this work, Shannon Entropy. There are some different approaches to quantify entropy in (RPs), from the classical ENTR to the recent recurrence microstate entropy. Although the fixed threshold in RQAs is widely used, we propose the use of maximum recurrence microstate entropy concept aimed to avoid several drawbacks and undesired analysis

bias. The maximum entropy concept defined as necessary to a correct evaluation of (RQAs) avoid the necessity of threshold choice, furthermore turn it into a new important quantifier, and avoid jeopardized evaluation on (RPs) and (RQAs). In this work we present the new approach applied on stochastic systems, nonlinear discrete and continuous dynamical systems, from the perspective of recurrence microstate entropy, threshold variations and recurrence rate. Moreover, the results present important connections among several quantifiers when unified by quite general concept, which can pave a way for a more general evaluation of dynamical systems by recurrence techniques. In our conclusions, will be presented the prospect on other quantifiers and real data, as climatological and biophysical systems.

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30 Nov
2:30pm
Room 6

Unstable equilibrium invading a stable one

Camila Castillo-Pinto, Marcel G. Clerc and Gregorio González-Cortés
Universidad de Chile, Chile.

Coexistence of states (either of stable or unstable nature) is an indispensable feature in the observation of domain walls, interfaces, shock waves or fronts in macroscopic systems. Propagation of these fronts depends on the relative stability of the connected equilibria. The intuition tells us that a stable equilibrium invades an unstable one, such as in combustion, the spread of permanent contagious diseases, or in the freezing of supercooled water. In this work, we show that in a one-dimensional model we can obtain the invasion of a stable state by an unstable one and we reveal the necessary features to observe this phenomenon. We show that in the context of pattern-forming systems, this family of non-linear waves are not only possible but also generic. The scenario is fulfilled in the subcritical spatial instability case. A photoisomerization experiment in a dye-doped liquid crystal cell allows us to observe this phenomenon.

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30 Nov
3:00pm
Room 5

Linear and nonlinear market correlations: Network based analysis of financial crises

Marcel Clerc[1], Michel Ferré[1], Saliya Coulibaly[2], René Rojas[3], and Mustapha Tlidi[4]
[1]Universidad de Chile, Chile; [2]Université de Lille, France; [3]Pontificia Universidad Católica de Valparaíso, Chile; [4]Université Libre de Bruxelles, Belgium.

We consider coupled-waveguide resonators subject to optical injection. The dynamics of this simple device are described by the discrete Lugiato-Lefever equation. We show that chimera-like states can be stabilized, thanks to the discrete nature of the coupled-waveguide resonators. Such chaotic localized structures are unstable in the continuous LugiatoLefever model; this is because of dispersive radiation from the tails of localized structures in the form of two counter-propagating fronts between the homogeneous and the complex spatiotemporal state. We characterize the formation of chimera-like states by computing the Lyapunov spectra. We show that localized states have an intermittent spatiotemporal chaotic dynamical nature. These states are generated in a parameter regime characterized by a coexistence between a uniform steady state and a spatiotemporal intermittency state.

Linear and nonlinear market correlations: Network based analysis of financial crises

30 Nov
3:00pm
Aula Magna

Alexander Haluszczynski[1], Cristoph Räth[2], Ingo Laut[2] and Heike Modest[2]
[1]Ludwig Maximilian University of Munich, Germany; [2]Deutsches Zentrum für Luft- und Raumfahrt, Germany.

Pearson correlation and mutual information based complex networks of the day-to-day returns of US S&P500 stocks between 1985 and 2015 have been constructed in order to investigate the mutual dependencies of the stocks and their nature. By deriving a measure for the strength of nonlinear correlations using surrogate data we show that a significant amount of information is lost when only relying on linear correlations measures. We find interesting observations particularly during periods of financial market crises. In contrast to the expectation that dependencies reduce mainly to linear correlations during crises we show that (at least in the 2008 crisis) nonlinear effects are significantly increasing. In general, both networks detect qualitative differences especially during (recent) turbulent market periods, thus indicating strongly fluctuating interconnections between the stocks of different companies in changing economic environments. Looking at different network topological measures, it turns out that the concept of centrality of a stock (node) within a network could potentially be used as some kind of an early warning indicator for abnormal market behavior as we demonstrate with the example of the 2008 subprime mortgage crisis. To put the information gain when also taking into account nonlinear dependencies into a practical context, we apply a Markowitz mean variance portfolio optimization and integrate our measure of nonlinear dependencies to scale the investment exposure. This leads to significant outperformance as compared to a fully invested portfolio with static exposure.[1]

References:

1. A. Haluszczynski, I. Laut, H. Modest, and C. Räth. Linear and nonlinear market correlations: Characterizing financial crises and portfolio optimization. Physical Review E, 96(6):062315, 2017.

Hippocampal and Cortical communication in mice sleep regulation

30 Nov
3:00pm
Room 6

Gustavo Lima[1], Sergio Lopes[2], Thiago Prado[2] and Gilberto Corso[1]
[1]UFRN; [2]UFPR

Transient intrusions of wakefulness into sleep have been associated with small irregular activity (SIA) in the hippocampus. To determine the precise temporal relationship between SIA and spontaneous micro-arousals, we investigated intracerebral local field potentials and mechanic acceleration during 175 micro-arousal episodes recorded from mice during slow-wave sleep. Moreover, the micro-arousals were preceded by hippocampal SIA, with a mean latency of 4.1 seconds during the light period when mice are more prone to sleep, and 2.8 seconds during the dark period when rats are more prone to waking. The latencies between changes in

cortical LFP and micro-arousals were significantly shorter. In this study we observed that micro-arousals were always preceded with a sharp decrease in hippocampal LFP power as well as frequency (peak frequency from 8.5Hz to 2.0Hz), followed by a slow monotonic decrease in the determinism of both hippocampal LFP and acceleration, then a sharp decrease in cortical LFP power, and finally abrupt body acceleration. The fact that overt mechanic movement is preceded by a subtle and yet inexorable loss of predictability in acceleration and hippocampal LFP signals implies that hippocampal and overall muscular activity are much more tightly coupled than previously considered.

Mini-Simposia

Complexity in Photonics: scaling down nonlinear dynamics in Optics

Nonlinear phenomena in parity-time symmetric photonics

Li Ge
City University of New York, United States

In this talk I will briefly discuss several interesting nonlinear phenomena in parity-time ($\mathcal{PT}$) symmetric photonics [1]. They include, for example, nonlinearity-induced spontaneous breaking of $\mathcal{PT}$ symmetry and dynamics of $\mathcal{PT}$-symmetric lasers. Due to light scattering, material absorption and a finite lifetime of confined optical modes, optics and photonics are intrinsically non-Hermitian with non-conserved photon flux or current. Usually these effects are ignorable when they are weak, but there are consequences of non-Hermiticity that are noticeable even in this limit. In the last ten years or so, the development of non-Hermitian photonics has been inspired by another field in physics, namely $\mathcal{PT}$-symmetry quantum mechanics and field theories. While the ramification of $\mathcal{PT}$ symmetry in quantum physics is still a topic under debate and investigation, theoretical proposals and experimental realizations of $\mathcal{PT}$-symmetric optics and photonics have led to a plethora of novel effects and important applications. They employ optical gain and loss in a well-controlled fashion, which prove to be essential tools of non-Hermitian physics and photonics. Generally speaking, $\mathcal{PT}$-symmetric systems have two distinguished phases, e.g., one with real-energy eigenvalues and the other with complex-conjugate eigenvalues. To enter one phase from the other, it is believed that the system must pass through an exceptional point, which is a non-Hermitian degenerate point with coalesced eigenvalues and eigenvectors. Here I will discuss an anomalous $\mathcal{PT}$ transition that takes place away from an exceptional point in a nonlinear system. $\mathcal{PT}$-symmetric lasers have also attracted considerable attention lately due to their promising applications and intriguing properties, such as free spectral range doubling and single-mode lasing. Here I will discuss how drastically different dynamics can take place in a $\mathcal{PT}$-symmetric laser at an exceptional point.

References:

1. L. Feng, R. El-Ganainy, and L. Ge, Non-Hermitian photonics based on paritytime symmetry, Nature Photonics 11, 752762 (2017).

Probing a dissipative phase transition via dynamical optical hysteresis

Said Rodriguez
Science Park Amsterdam, The Netherlands.

I will discuss the reaction time of laser-driven optical microcavities with Kerr-type nonlinearity, and the influence of quantum fluctuations on their response. By scanning the laser power across a bistability at variable rates, we observed a double power-law decay of the hysteresis area as a function of the scanning time. The transition from one power law to another can occur on time scales vastly greater than the photon lifetime. Approaching the thermodynamic limit of high photon densities, the double power-law becomes a single power-law thereby leading to a dissipative phase transition. I will conclude with perspectives for experiments with tunable nonlinear photonic lattices.

Nonlinear dynamics in photonic crystal Fano lasers

Jesper Mork, Thorsten Rasmussen and Yi Yu
Technical University of Denmark, Denmark.

In this talk we discuss the dynamical properties of a novel type of laser, where one of the mirrors is based on a Fano resonance. This gives rise to a mirror with narrow bandwidth and large optical nonlinearity and the laser displays dynamical properties very different from conventional lasers. In particular, it is shown that the laser gives rise to fast self-pulsing and has increased tolerance towards optical feedback. Furthermore, the laser has the potential to be modulated at frequencies far beyond the relaxation oscillation frequency of the laser. In the talk, we will emphasize the theoretical modelling of the laser but also describe the experimental realization of Fano lasers using photonic crystal waveguides and point-defect nanocavities.

Pulse train dynamics in an excitable laser with delayed optical feedback

Bernd Krauskopf[1], Soizic Terrien[1], Neil Broderick[1] and Sylvain Barbay[2]
[1]The University of Auckland, New Zealand; [2]Centre de Nanosciences et de Nanotechnologies, France.

Recent experiments demonstrated that an excitable VCSEL micropillar laser with delayed optical feedback is able to sustain trains of optical pulses. These can be triggered largely independently by optical perturbations and sustained simultaneously in the external cavity. A bifurcation analysis of a rate-equation model shows that the system has a number of periodic solutions with different numbers of equally spaced pulses as its only attractors. Hence, although coexisting pulse trains can seem independent on the timescale of the experiment, they correspond to extremely long transient dynamics. Moreover, the switching dynamics can be investigated by studying the associated basins of attraction.

Dynamical behaviour of coupled passive optical resonators

Neil Broderick[1], Bernd Krauskopf[1], Alejandro Yacomotti[2], Ariel Levenson[2] and Andrus Munoz[1]

[1]The University of Auckland, New Zealand; [2]Université Paris-Sud, France.

The dynamics of passively coupled photonic crystal resonators presents a wealth of interesting physics including, bistability, chaos and low threshold lasing for example. Using the modified Bose-Hubbard model we will present a bifurcation analysis of these resonators and highlight parameter regimes where such behaviour can be found. Importantly we have found that for experimentally realistic parameters Shilnikov bifurcations leading to regions with positive Lyapunov exponents proving that this system can behave chaotically.

This analysis complements the earlier experimental work done at C2N and also it is hoped will lead into the quantum regime as described by the Bose-Hubbard model providing new insights into quantum chaos.

Phase Stochastic Resonance in a Forced Nanoelectromechanical Membrane

Marcel Clerc

Universidad de Chile, Chile.

Stochastic resonance is a general phenomenon usually observed in one-dimensional, amplitude modulated, bistable systems. In this presentation, We show experimentally the emergence of phase stochastic resonance in the bidimensional response of a forced nanoelectromechanical membrane by evidencing the enhancement of a weak phase modulated signal thanks to the addition of phase noise. Based on a general forced Duffing oscillator model, we demonstrate experimentally and theoretically, that phase noise acts multiplicatively, inducing important physical consequences. These results may open interesting prospects for phase noise metrology or coherent signal transmission applications in nanomechanical oscillators. Moreover, our approach, due to its general character, may apply to various systems.

About real optical vortices in laser systems

Jorge Tredicce[1], Patrice Genevet[2], Stephane Barland[3] and Massimo Giudici[3]

[1]Universite de la Nouvelle Caledonie, France; [2] CHREA - CNRS, France; [3]Universite de la Cote d'Azur, France.

We studied an optical system consisting in a VCSEL coupled to a cavity containing a saturable absorber. The whole system has a large aspect ratio. We observe the appearance of optical vortices in a sufficiently large values of the control parameters. The vortices do not correspond to Gauss Laguerre modes of the resonators but they are generated exclusively from the nonlinear interaction between radiation and matter. By interference we show experimentally the existence of the vortices as well as their independence while they coexist in the system. We discuss the relevance of the phase symmetry in allowing the formation of such optical vortices.

Coupled Nanolasers, a Laboratory for Nonlinear Dynamics and Nonequilibrium Phenomena

Ariel Levenson[1], Julien Javaloyes[2], Mathias Marconi[3], Fabric Raineri[1] and Alajandro Giacomotti[1]

[1]C2N-CNRS, France; [2]Universitat de les Illes Balears, Spain; [3]INPHYNI-CNRS, France.

Beyond their intrinsic assets for numerous applications, coupled nanolasers obtained in 2D Photonic Crystals constitute an interesting playground for nonlinear dynamical and far from equilibrium physics. They allow of controlling the level of the nonlinearity, the coupling between nanolasers/modes, the detuning between nanocavities, and more importantly their relative strength. On the light of the two limit cases of nanolasers coupling smaller and stronger than nonlinearity, we will discuss spontaneous symmetry breaking, mode switching and quenching as well as statistical emission properties.

Nonlinear Dynamics as a language for Biology

Microswimmers and microfluidics: applications from health and environment to agriculture.

Veronica I. Marconi

Universidad Nacional de Córdoba, Argentina.

In Physics the nonlinearities dominate most of problems and applications as they do in Life Sciences, but a distinctive feature in biological science is the huge number of DNA molecules, proteins, cells, organisms in a population, organs, and so on. And even more, the immense number of items being studied in the life sciences are heterogeneous, rather than homogeneous as in the physical sciences, and in addition they interact mostly nonlinearly.

In our numerical and experimental multidisciplinary work we aim to understand the physics of problems in biology. In particular we investigate the complex relation between populations of self-propelled microorganisms and the confinement geometry in order to optimise the design of microfluidics devices for a wide number of applications: human reproduction (sperm cells), filtration and ecology (bacteria), biofertilizers and sustainable agronomy (bacteria), evolution biology (choanoflagellates). In all these applications, the nonlinear interactions and heterogeneities are dominant features of the problems which will be highlighted in this presentation.

Robotic vehicles as a tool to study the neural basis of locomotor activity

Pablo Gleiser and Carlos Eduardo Valencia Urbina

Centro Atómico Bariloche, Argentina.

In this work we used a robotic vehicle to study the neural basis of locomotor activity in the nematode C. elegans. Using a robot has a specific advantage over a biological model, since it is possible to access and have control over all the ingredients that governs its behavior. At the same time it also allows for the implementation of a complex system that is subject in a natural way to the laws of physics in its interaction with a real environment. In particular, we implemented a numerical simulation of the neural system of the nematode C. elegans in a robotic vehicle. The environmental information is obtained by using a distance sensor that transmits information directly to sensory neurons, and locomotor activity is controled by electric motors that are connected and receive information from the corresponding muscle output. We found that, as was observed experimentally in the C. elegans brain by Kato et al. (Cell 163, 656669, October 22, 2015), a large proportion of the simulated neurons across the brain share information by engaging in coordinated, dynamical network activity. Also, as in the experiments by Kato et al., the simulation evolves on a smooth cyclical dynamics, where different segments, that correspond to the activities of different neuronal sub-populations, can be mapped to represent action sequences of the robot. Our results show the robustness of the brain dynamics of

C. elegans, and also how robotics can contribute to the understanding of the neural basis of locomotor activity.

Anticipated synchronization in the brain

Mauro Copelli

Federal University of Pernambuco, Brazil

Anticipated synchronization (AS) is a counterintuitive regime that can occur in a sender-receiver configuration, where the latter can predict the future dynamics of the former for certain parameter values. AS has been found both experimentally and numerically in different fields, such as optics and electronic circuits. Later, the phenomenon was extended to neuroscience. On the one hand, AS was shown to occur for biologically plausible models of neuronal activity. On the other hand, models exhibiting AS were able to explain the apparent discrepancy between information flow and time lag observed experimentally in the cortical activity of monkeys. We will review the current state of the field and outline the possibilities and challenges ahead.

Species extinction in complex ecological networks

Fabiana Laguna

Centro Atómico Bariloche, Argentina

The mathematical modeling of ecological interactions is an essential tool in predicting the behavior of complex systems across changing scenarios, such as those arising from climate change or environmental degradation.

The literature abounds with examples of predatorprey models, of intra- and inter-specific competition, of the relation between species richness and area size and of habitat fragmentation. However, considerable effort still needs to be made in the integration of all these mechanisms together.

With the purpose of advancing towards the study of trophic web complexity in successive approximations, we started a few years ago the development of metapopulation models of generic predatorprey-competition systems coexisting in environments subjected to disturbances. The use of both, ordinary differential equations and stochastic simulations, allowed us to obtain the average behavior of the relevant variables but also to study the role of uctuations and spatial correlations.

I will present some recent results obtained with more realistic versions of the models we initially explored [1,2].Besides the typical regimes of coexistence and extinction of species, persistent temporal and spatial oscillations appear in some regions of the parameter space. The phenomenon is not present for the more idealized models, suggesting that it can be the source of real ecosystems oscillations.

[1]Laguna MF, Abramson G, Kuperman MN, Lanata JL, Monjeau JA, Mathematical model of livestock and wildlife: Predation and competition under environmental disturbances, Ecological Modeling 309-310 (2015) 110-117.

[2] Abramson G, Laguna MF, Kuperman MN, Monjeau JA, Lanata JL, On the roles of hunting and habitat size on the extinction of megafauna, Quaternary International 431B (2017) 205-215.

Open problems in chaotic dynamics and their impact in dynamical astronomy and multi-particle systems

The Contribution of Dwarf Planets to the Origin of Low-inclination Comets by the Replenishment of Mean Motion Resonances in Debris Disks

Barbara Pichardo[1], Marco Muñoz[2] and Antonio Peimbert[1]

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In this work we explore a new dynamical path for the delivery of low-inclination comets. In a configuration formed by an interior giant planet and an exterior massive debris disk, where the mass is accounted for by the 50 largest objects in the disk, the strongest mean motion resonances of the giant, located along the belt, are replenished with new material (test particles) due to the influence of the 50 massive objects. Once in resonance, slow chaotic diffusion stirs the orbital elements of the cometary nuclei enough to encounter the giant and to be scattered by it. When the disk is massive enough, both resonant and non-resonant particles are stirred quickly to encounter the giant and form a scattered disk component, greatly increasing the rate for the delivery of cometary material to the inner part of the system. This mechanism is applicable both to the solar system and extrasolar systems in general. Preliminary results, using a disk as massive as the classical Kuiper Belt, indicate that the mechanism proposed here can account for about a tenth of the required injection rate to maintain the population of ecliptic comets in steady state. In a more massive belt of 0.25 $M_\odot$, an estimated rate of around 0.6 new comets per year is found. Such a high rate would pose a serious risk for the habitability of rocky interior planets, yet would resemble the late heavy bombardment that was present in the early solar system.

Modeling flares in the solar corona coupling SOC models and magnetic reconnection

Laura Morales[1] and Paul Charbonneau[2]

[1]Universidad de Buenos Aires, Argentina; [2]University of Montreal, Canada

Solar flares are the manifestation of intermittent and impulsive release of energy in the corona. The spatial coincidence of flares with magnetic structures at the solar surface leaves no doubt that flares draw their energy from the Suns magnetic field. Moreover, their very short onset time points to magnetic reconnection as the physical mechanism responsible for extracting that energy. Systematic studies of flares observed from the extreme ultraviolet to soft X-rays revealed (Dennis, 1985; Aschwanden, 2011 and references there in) that the frequency distribution of solar flare energy release follows a well-defined power law, spanning 8 orders of magnitude in flare energy. In the early '90s Lu & Hamilton proposed a way to explain the observed power-laws assuming that solar flares are avalanches of several reconnection events occurring in a solar coronal loop. We have designed an avalanche model for solar flares that uses magnetic field lines as basic dynamical elements. We assume an idealized representation of a coronal loop as a bundle of magnetic flux strands wrapping around one another. The model is based on a two-dimensional cellular automaton with anisotropic connectivity, where linear ensembles of interconnected nodes define the individual strands collectively making up the coronal loop. The system is driven by random deformation of the strands, and reconnection is mimicked whenever the angle subtended by two strands crossing at the same lattice site exceed some preset threshold. We have shown that this system produces avalanches of reconnection events characterized by scale-free size distributions that compare very well with existing observations (Morales & Charbonneau, 2008 and 2009). In this work we extend the models predicting capabilities of extreme flares by characterizing the stress pattern developed by the coronal loop when a the biggest avalanches take place.

Restrictions to Spiral Arms Parameters in Galaxies using Ordered and Chaotic Stellar Orbital Studies

Angela Perez Villegas[1] and Barbara Pichardo[2]

[1]University of São Paulo, Brazil; [2]Universidad Nacional Autónoma de México, Mexico.

Making use of a set of detailed potential models for normal spiral galaxies based on the observational rotation curve, we analyze disk stellar-orbital dynamics as the structural and dynamical parameters of spiral arms (mass, pattern speed, and pitch angle) are gradually modified. With this comprehensive study of ordered and chaotic behavior, we constructed an assemblage of orbitally supported galactic models and plausible parameters for orbitally self-consistent spiral arm models. We find that to maintain orbital support for the spiral arms, the spiral arm mass, Msp, must decrease with the increase of the pitch angle, these values depend on the total mass galaxy. For values larger than the limits allowed by each galaxy mass, spiral arms would likely act as transient features. Regarding the limits posed by extreme chaotic behavior, we find a strong restriction on the maximum plausible values of spiral arm parameters on disk galaxies beyond which chaotic behavior becomes pervasive, dominating phase space and destroying the main periodic orbits and the neighboring quasiperiodic orbits.

Periodic orbits of very high period in area preserving maps

Arturo Olivera

Universidad Nacional Autónoma de México, Mexico

Computation of periodic orbits in a discrete dynamical systems has been a usefull tool in Celestial and Classical Mechanics. The search of high order periodic orbits in 2D symplectic maps has been done efficiently only on maps with symmetries that reduce the search from the actual 2D phase space to 1D, in this case it is possible to compute periodic orbits with periods higher than 10^6. A modified version of the parameterization method introduced by de la Llave et al. is implemented to estimate periodic orbits in any given two dimensional symplectic map. The benchmark used to test the proposed method is a three parameter analytic ratchet-like map studied before by Simo-Olvera-Petrov that lacks of symmetry lines for a generic election of the parameters.

On the dynamics of Comet 1P/Halley

Luis Benet and Jorge A. Hernández-Pérez

Universidad Nacional Autónoma de México, Mexico

The dynamics of Comet 1P/Halley has recently attracted some attention (Muñoz-Gutiérrez et al, 2015; Boekholt et al 2016). The models used consider a Newtonian N-body model which is integrated for few thousand years. While it is undisputed the chaotic dynamics of the comet, the inverse of the maximum Lyapunov exponent, the Lyapunov time, has given rise to some controversy. In this talk, we present results of precise numerical integrations spanning 10^5 years for the whole Lyapunov spectrum of Halley's orbit and for its power spectrum. We discuss the implications of our results on the causes of the chaotic dynamics of the comet.

Localization in inhomogeneous FPU lattices

Panayotis Panayotaros and Francisco Martinez-Farias

Universidad Nacional Autónoma de México, Mexico.

We study localized oscillations in quartic Fermi-Pasta-Ulam dynamics in graphs, a problem motivated by some “elastic lattice” models for protein vibrations. The main feature of these lattices is that the number of interacting neighbors is site dependent. Nonlinear localization is studied by continuation from linear localized modes, combining information on the linear graph spectrum and normal form analysis of resonant interactions. At the moment we can show the existence of localized modes in Birkhoff normal forms, using the existence of invariant spaces with additional symmetries. The periodic orbits are then relatively equilibria in the invariant subspace. We examine examples of localized modes in 1-D lattices and in two 3-D lattices with protein geometries obtained from crystallographic data (ribozyme and subticilin). We also present some numerical results indicating nonlinear stability of localized motions in 1-D random lattices that share some features of the 3-D examples. This is joint work with Francisco Martinez-Farias Universidad Autonoma del Estado de Hidalgo, Apan, Mexico.

Characterization of chaotic diffusion: a Shannon entropy approach

Pablo Cincotta

Universidad Nacional de La Plata, Argentina.

In the present talk I will discuss two new estimators of chaotic diffusion based on the Shannon entropy. Using theoretical, heuristic and numerical arguments I show that the entropy, S, provides a measure of the diffusion extent of a given small initial ensemble of orbits, while an indicator related with the time derivative of the entropy, S', estimates the diffusion rate. In the limiting case of near ergodicity, after an appropriate normalization, S' coincides with the expected homogeneous diffusion coefficient. Applications to 4D symplectic maps and the Arnold Hamiltonian will be addressed.

Also I will briefly show that the Shannon entropy is also very useful to investigate phase correlations, in particular to unveil strong correlations in the time evolution of the phases involved in the Arnold’s Hamiltonian that lead to anomalous diffusion. In this direction, I discuss the validity of several approximations and assumptions usually introduced to derive a local diffusion coefficient in multidimensional near-integrable Hamiltonian systems, in particular the so-called reduced stochasticity approximation.

Nonlinear time series analysis, extreme events, and applications

Climate networks and atmospheric teleconnections

Marcelo Barreiro
Universidad de la República, Uruguay

The development of new approaches for data analysis such as the use of complex networks has allowed significant advances in our understanding of climate variability and change. In this talk I will present how the application of the complex network approach has yielded new insights into atmospheric teleconnections. In particular, I will focus on the detection and variability of atmospheric connectivity during the XX century and how it might change under anthropogenic forcing.

Agenda diversity and coverage bias: A quantitative approach to the agenda-setting theory

Sebastián Pinto, Claudio D. Orso and Pablo Balenzuela
Universidad de Buenos Aires, Argentina

The mass media play a fundamental role in the formation of public opinion, either by defining the topics of discussion or by making a degree of emphasis on certain issues. Directly or indirectly, people get informed by consuming news from the media. But which is the dynamic of the agenda and how the people becomes interested in the different topics of the agenda? The Agenda Setting theory provides a conceptual framework in order to understand the role played by the mass media in public opinion formation, but the previous questions can not be answered without proper quantitative measures of agenda's dynamic and public attention. In this work we study the agenda of Argentinian newspapers in comparison with public interests through a quantitative approach by performing topic detection over the news, identifying the main topic covered and their evolution over time. We measure Agendas diversity as a function of time using Shannons entropy and difference between Agendas using Jensen-Shannons distance. We found that the Public Agenda is less diverse than the Media Agenda, and we are also capable to detect periods of time where coverage of certain issues are biased (coverage bias).

Symbolic Correlation Tools: Integrals and Recurrence Plots

Mariano Matilla-García

Universidad Nacional de Educación a Distancia, Spain.

Recurrence plots, correlation integrals and symbolic pattern analysis are standard concepts (and tools) the palette of any researcher in nonlinear science. We investigate how symbolic recurrence plots and their derived measures can be easily used as productive tools to analyze the dynamic structure of dynamical systems. Symbolic recurrences are introduced under the theoretical support of the concept of symbolic correlation integral. A symbolic recurrence plot have several advantages: (i) it can be used for stationary and nonstationary data sets; (ii) it is robust to noise and invariant under certain data transformations; (iii) it can be used as a tool for diagnostic analysis given its statistical support.

Detecting directional couplings from multivariate flows by the joint distribution distance

José María Amigó[1] and Yoshito Hirata[2]

[1]Universidad Miguel Hernandez, Spain; [2]The University of Tokyo, Japan.

Given a dataset of multivariate time series measured at various points in a network, a basic question is how these points are causally connected with each other. To answer this question, various methods have been proposed ranging from the Granger causality to the transfer entropy and the convergent cross mapping. But an important problem has been missed in a practical setting, to wit: whether we can infer a directional coupling correctly under the existence of a common hidden driver. In this talk we present our approach for inferring directional couplings from a set of multi- variate time series based on Starks embedding theorem for a forced system. In particular, we discuss the key point, namely, that one can reconstruct the information of the driver from observations at the response system but not the other way around.

Application of Central Tendency Measure for RR Intervals Time Series

Laurita Dos Santos[1], Celso B. N. Freitas[2], Liliam M. Araujo[1], Joaquim J Barroso[2] and Elbert Macau[2]

[1]Universidade Brasil, Brazil; [2]National Institute for Space Research, Brazil.

Several tools are used in Heart Rate Variability (HRV) analysis and its relationship with Autonomic Nervous System (ANS). The simplest noninvasive way to analyze HRV is using RR intervals time series, where each RR represents the difference between two R waves on the electrocardiogram. It is important to understand the connection HRV - ANS and how it can affect the homeostasis of the individual. HRV gives information about the healthy variability, where greater variability indicates individual in healthy condition. It is known that momentarily stressful and pathological conditions alter ANS. Although there is difficult to detect and differentiate between both situations cited above, they may alter the ANS. In the case of the alteration causes by momentary stress, it can be reversed and normalized at ANS level. The main purpose of this study is to discriminate these cases from each other using nonlinear tools. To this end, we propose a new approach based on Central Tendency Measure (CTM) for classifying disturbs of the ANS involving HRV, which we name Extended CTM (e-CTM). Basically, the method analyzes the differences between RR intervals using an empirically chosen delay (P) considering a radius (r). The experimental dataset is divided in three groups: subjects with congestive cardiac failure, healthy subjects and subjects during one hour of their workday. The results indicate that, in subjects with diagnosed pathologies, e-CTM(r, P) gets the maximum value (e-CTM(r, P) 1) with small r, instead of (e-CTM(r, P) $<$ 1) from individuals without diagnosed pathology. This approach seems promising as a method to differentiate groups of individuals with diagnosed pathology from those with momentary situations of ANS alteration, where more data tests are necessary.

A novel network modelling approach for EEG-microstate dynamics during loss of consciousness

Jennifer Creaser[1], Peter Ashwin[1], Claire Postlethwaite[2] and Juliane Britz[3]

[1]University of Exeter, United Kingdom; [2]University of Auckland, New Zealand; [3]University of Fribourg, Switzerland.

In a resting state, large scale neurocognitive networks dynamically and rapidly evolve on millisecond timescales, in order to optimise the system for a given impending input. The timing of these dynamics is crucial to consciousness, cognition and perception. Here we analyse time series of brain activity recorded using an electroencephalogram (EEG) to identify changes in the intrinsic temporal organisation of the brain dynamics during pharmacologically induced loss of consciousness. We convert the EEG data into sequences of EEG-microstates, epochs with variable durations (typically 80-120ms long) in which the topography of the scalp electric field is fixed but the polarity can invert. Sequences of microstates are becoming an increasingly popular time-series analysis tool to study cognition and perception as well as a variety of neurological disorders including Alzheimer's Disease, schizophrenia, and depression. Each microstate provides a measure of overall momentary brain activity as a spatial summation of all concurrently active intracranial sources. The fast switching between microstates is indicative of rapid sequential activation of different underlying brain networks. In healthy resting state data, brain activity has been consistently shown to visit four different microstates, with characteristic patterns of transition between each. Sequences of microstates have been shown to have scale-free or fractal temporal structure indicative of the long range dependencies that are an intrinsic property of neural dynamics. Here, we examine the effect of anaesthetic on microstate sequences and propose a novel modelling approach. The residence times of each of the four microstates have heavy tailed distributions that change as the level of awareness decreases, along with the transition probabilities and measure of long range temporal correlations. We construct noisy network attractor models in which each node is one of the microstates and show how the models capture the observed statistical properties of the sequences.

Extreme events in two delay-coupled FitzHugh-Nagumo oscillators

Arindam Saha and Ulrike Feudel

University Oldenburg, Germany.

We demonstrate that time-delayed coupling of two FitzHugh-Nagumo oscillators can cause extreme events and propose a mechanism for the dynamical properties observed. We show that extreme events occur between a bubbling transition and a blowout bifurcation. Thereafter, we analyze the system in a multistable regime and charaterize the basin structure for extreme events. We show that 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.

Recurrency density enhanced approach

Elbert Macau[1], Barbara Maximo[1], Young Zou[2] and Marcos Quiles[3]

[1]Instituto Nacional de Pesquisas Espaciais, Brazil; [2]East China Normal University, China; [3]Federal University of São Paulo, Brazil.

We present a transformation method, entitled Recurrence Density Enhancement Approach (RDE), that aims to highlight the main recurrence structures of a given recurrence plot (RP). Our method results in a figure with a reduced number of points yet preserving the main and fundamental properties of the original plot. The existing measures of quantification analysis are applied to characterize the underlying dynamical system. Our evaluation results indicate that our proposed approach allows to discriminate different dynamic regimes adequately, while using a reduced set of points from the original RP.

Posters

Tuesday Session.

Dynamic vaccination in partially overlapped multiplex network

Lucila G. Alvarez-Zuzekh[1], Matias A. Di Muroh[1], Shlomo Havlinh[2] and Lidia A. Braunsteinh[1]

[1]IFIMAR-UNMdP, Argentina; [2]Bar-Ilan University, Israel.

The spread of epidemics has always been a matter of interest due to its catastrophic effects that it may inflect in a society. This issue has been behind the motivation of many investigations that tried to develop different mitigation strategies to diminish the impact of diseases spreading. In this work we propose a new strategy of vaccination, called dynamic vaccination. In our model, susceptible people become aware that one of their contacts are infected, and thereby get vaccinated with probability ω, before having physical contact with any infected patient. Then, the non-vaccinated individuals will be infected with probability β. We apply the strategy to the SIR epidemic model in a multiplex network, where a fraction q of the nodes acts in all networks. We map this model of dynamic vaccination into bond percolation, and use the generating functions framework to predict theoretically the behavior of the relevant magnitudes of the system at the steady state. We find a perfect agreement between the solutions of the theoretical equations and the results of stochastic simulations. In addition, we find an interesting phase diagram in the plane $\beta-\omega$, which is composed by an epidemic and a non-epidemic phases, separated by a critical threshold line β_c, which depends on q. As q decreases, β_c increases, *i.e.*, as the overlap decreases, the system is more disconnected, therefore more virulent diseases are needed to spread epidemics. Surprisingly we find that, for all values of q, a region in the diagram where the vaccination is so efficient that, regardless of β, it never becomes an epidemic. We compare our strategy with random immunization and find that vaccinating dynamically is much more efficient. Using the same amount of vaccines, we obtain that the spread of the disease is much lower in the case of dynamic vaccination.

Multiple outbreaks in epidemic spreading with local vaccination and limited vaccines

Matias A. Di Muroh[1], Lucila G. Alvarez-Zuzekh[1], Shlomo Havlinh[2] and Lidia A. Braunsteinh[1]

[1]IFIMAR-UNMdP, Argentina; [2]Bar-Ilan University, Israel.

How to prevent the spread of human diseases is a great challenge for the scientific community and so far there are many studies in which immunization strategies have been developed. However, these kind of strategies usually do not consider that medical institutes may have limited vaccine resources available. In this manuscript, we explore the Susceptible-Infected-Recovered (SIR) model with local dynamic vaccination, and considering limited vaccines. In this model, susceptibles in contact with an infected individual, are vaccinated -with probability ω- and then getting infected -with probability β. However, when the fraction of immunized individuals reaches a threshold V_L, the vaccination stops, after which only the infection is possible. In the steady state, besides the critical points β_c and ω_c that separate a non-epidemic from an epidemic phase, we find for a range of V_L another transition points, $\beta^* > \beta_c$ and $\omega^* < \omega_c$, which correspond to a novel discontinuous phase transition. This critical value separates a phase where the amount of vaccines is sufficient, from a phase where the disease is strong enough to exhaust all the vaccination units. For a disease with fixed β, the vaccination probability ω can be controlled in order to drastically reduce the number of infected individuals, using efficiently the available vaccines.

Furthermore, the temporal evolution of the system close to β^* or ω^*, shows that after a peak of infection the system enters into a quasi-stationary state, with only a few infected cases. But if there are no more vaccines, these few infected individuals could originate a second outbreak, represented by a second peak of infection. This state of apparent calm, could be dangerous since it may lead to misleading conclusions and to an abandon of the strategies to control the disease.

An Alternative Method for Computing the Dimension of Fractal Basin Boundaries

Vitor de Oliveira[1] and Rafael Vilela[2]

[1]University of São Paulo, Brazil; [2]Universidade Federal do ABC, Brazil.

There are currently two main methods used to calculate the dimension of fractal basin boundaries in dynamical systems, namely the *uncertainty method* and the *output function evaluation method*. We propose a new method that is based on the former one called the *conditional uncertainty method*. We show that the conditional uncertainty method can calculate fractal dimensions of basin boundaries to a good accuracy.

Fermi acceleration in time-dependent billiards

Matheus Hansen[1], David Ciro[2], Iberê L. Caldas[1] and Edson D. Leonel[3]

[1]Universidade de São Paulo, Brazil; [2]Universidade Federal do Paraná, Brazil [3]UNESP, Brazil.

The changeover from normal to super diffusion in time dependent billiards is explained analytically. The unlimited energy growth for an ensemble of bouncing particles in time dependent billiards is obtained by means of a two dimensional mapping of the first and second moments of the speed distribution function. We prove that, for low initial speeds the average speed of the ensemble grows with exponent $\sim 1/2$ of the number of collisions with the boundary, therefore exhibiting normal diffusion. Eventually, this regime changes to a faster growth characterized by an exponent ~ 1 corresponding to super diffusion. For larger initial energies, the temporary symmetry in the diffusion of speeds explains an initial plateau of the average speed.

Lie Symmetry Reduction of a Nonholonomic Mechanical System via Moving Frames

Cláudio Henrique Cerqueira Basquerotto[1], Edison Righetto[2] and Samuel Da Silva[2]

[1]Universidade Federal do Sul e Sudeste do Pará, Brazil; [2]Universidade Estadual Paulista, Brazil.

The extraction of Lie symmetries in motion equations can be used to reduce the order and to obtain conservation quantities. These invariants are very useful for decoupling and to find the exact solutions of differential equations. Additionally, the classification of motion equations, i.e., to apply a transformation to obtain an already known solution of a mapped equation, can be effectuated with a Cartan's moving frame theory. In this case, the motion equation can be interpreted by surfaces of equivariant moving frames. In order to illustrate the approach a nonholonomic constrained mechanical system of Chetaev type is solved to obtain a general closed-solution in explicit form. This example is a dog pursuing a man in a plane surface with a nonholonomic constraint. A full detailed analysis is discussed to explain the Lie symmetries and the correspondent moving frame obtained.

Nonlinear Control of an Inverted Pendulum using Two Reaction Wheels

João Francisco Silva Trentin[1], Samuel Da Silva[1] and Hanspeter Schaub[2]
[1]Universidade Estadual Paulista, Brazil; [2]University of Colorado Boulder, United States.

Angular momentum exchange devices such as reaction wheels have been used for attitude control in spacecraft, satellites and robots, being one of the most popular ways to stabilize and reject disturbances in such devices. From the controlled change of angular momentum rate of change, it is possible to control the oscillation and direction rate of change in rigid bodies in space. Thus, in the present paper is shown the complete model of the Two Reaction Wheels Pendulum (2-RWP) and a nonlinear controller design using the Lyapunov control theory. This controller has the feature of choosing how active each control action is. In this way, it is also evaluated the difference of actuating a pendulum using one reaction wheel, using two or using one more than the other. A full detailed analysis of the simulated results is discussed to explain the differences in the use of the actuators.

Dynamics of a near singular billiard: A Lyapunov exponent and recurrence analysis

Rodrigo Baroni and Ricardo de Carvalho
UNESP, Brazil.

In this work we investigate the classical dynamics of a particle in the circular billiard with an almost punctual scatterer. The model considered is the annular billiard, which consists of a particle confined in the annular region between two circumscribed circles, we then choose the radius r of the inner circle to be much smaller than the radius $R = 1$ of the outer boundary, i.e. $r << R$. The transition from the regular annular billiard to the near singular billiard is identified as an abrupt decrease of the largest Lyapunov exponent when r reaches a certain value. We show, for the static boundary case, that the phase space of the near singular billiard is regularly filled with straight lines by a single initial condition (IC). The recurrence plot (RP) of the phase space orbit and the application of Slater's Theorem shows that this IC is chaotic but composed of quasi-periodic segments. By adding a time-dependent perturbation to the boundary, the particle may gain or lose energy after each collision with the boundary, RP's of the trajectories in the 4-dimensional phase space are used to identify the times when the particle is caught by stickiness.

Special Sensitive. part1 Fundamental state of Catastrophe

Mauricio Díaz
Universidad Nacional Andrés Bello, Chile.

In this article we research a chaotic MDS-type1 system with E-system, topological entropy and limit set with α-Baire class as indicator to the existence of a sensitive system. For this work, we going to associate the sensitive R-group with the presence of a n-uncountable scrambled tuple elements and we going to prove that any (X,T) can be chaotic for any value of h_T and $\alpha(\omega_T(x))$ taking algebraic properties of X and 2^ω as equivalent. For this case, we research the possibility of obtain a chaotic system from a countable group. Finally we introduce the concept of Catastrophe and we define it as a general concept of sensitive system.

Parameter space for a family of dissipative two-dimensional mappings

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The parameter plane investigation for a family of two-dimensional, nonlinear and area contracting map is studied. Several dynamical features in the system such as tangent, period-doubling, pitchfork and cusp bifurcations were found and discussed together with cascades of period-adding, period-doubling, and the Feigeinbaum scenario. The presence of spring and saddle-area structures allow us to conclude that cubic homoclinic tangencies are present in the system. A set of complex sets such as streets with the same periodicity and the period-adding of spring-areas are observed in the parameter space of the mapping.

Scaling laws and critical exponents in Smith and Slatkin model

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We derived explicit forms for the convergence to the steady state for a one-dimensional Smith and Slatkin mapping at and near at bifurcations. We used a phenomenological description with a set of scaling hypothesis leading to a homogeneous function giving a scaling law. The procedure is supported by numerical simulations and confirmed by a theoretical description. At the bifurcation we used an approximation transforming the difference equation into a differential one whose solution remount all scaling features. Near the bifurcation an investigation of fixed point stability leads to the decay for the stationary state. Simulations are made in the pitchfork, transcritical and period doubling bifurcations.

Recurrent Equations for Computing Rate-Coded Spikes of a Stochastic Integrate-and-Fire Neuron

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The brain, with billions of excitable elements – the neurons – is the most complex system presently known. In this research we study a stochastic integrate-and-fire neuron model [1] to understand more about the transfer function of a single neuron. In our discrete-time model, neuron firing events have a stochastic dependency on the neuron membrane potential. The membrane potential of the neuron is reseted after its spike, losing all information of previous time steps. We assume that the sum of all inputs of a neuron can be approximated by as a slowly-varying mean current (the signal) plus a Gaussian noise term. With this model, we derive recurrence equations that describe completely the neuron output by its distribution of inter-spike intervals. This analysis will be useful when modeling neuronal circuits that operate with rate-coded information. We present phase diagrams for different input averages and Gaussian deviations.

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Inference of topology and the nature of synapses in neuronal networks

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The characterization of neuronal connectivity is one of the most important matters in neuroscience. In this work, we show that a recently proposed informational quantity, the causal mutual information, employed with an appropriate methodology, can be used not only to correctly infer the direction of the underlying physical synapses, but also to identify their excitatory or inhibitory nature, considering easy to handle and measure bivariate time series. Our work reveals a surprising phenomenon in neural networks, in which a pre-synaptic neuron (a neuron that has an adjacent connection to the post-synaptic one) not only exchange information (positive mutual information), but is also capable of using information to cause an effect in a post-synaptic neuron (positive transfer entropy). Non-adjacent neurons only exchange information. We also demonstrate that our methodology can be used to correctly infer directionality of synapses even in the presence of dynamic and observational Gaussian noise, and is also successful in providing the effective directionality of inter-modular connectivity, when only mean fields can be measured.

Turnstiles as a mechanism of increasing the flux of trajectories in Hamiltonian systems

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The study of transport in Hamiltonian systems aims to characterize the motion of groups of trajectories from one region of the phase space to another. A description of transport is particularly difficult in non-integrable Hamiltonian systems, due to the fact that the phase space presents a coexistence between periodic, quasiperiodic an chaotic orbits. The transport in twist Hamiltonian systems is known and it is described by turnstiles and resonance zones. In this work, we aim to characterize the transport in Hamiltonian system where the twist condition is violated: the nontwist systems. An example of the nontwist system, which has been intensively studied in the past two decades, is the standard nontwist map (SNM). We take this map as a paradigm for the dynamical behavior of nontwist systems. The violation of the twist condition by the SNM has as a consequence the existence of twin island chains, the shearless curve and diverse bifurcations like periodic orbit collision and separatrix reconnection. The island chains bordering the shearless curve act like barriers for the transport in the phase space and only after the shearless curve is destroyed is there transport across the internal partial barrier. The transport flux through the barrier has been characterized numerically by the transmissivity which is zero if there is a full barrier in the phase space. When the barrier is broken, the chaotic trajectories can cross the resonance zones, increasing the flux through the phase space. The turnstiles are the responsible mechanism for increasing of the transport, just in the way that they do for twist systems. We also studied the escape basins and the entropies associated to them to quantity the unpredictability of the system.

Heat conduction in coupled one-dimensional chains with long-range interactions

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We study numerically the energy transport along two one-dimensional chains of atoms time-dependent coupled. The atoms are subjected to an on-site potential and to long-range interactions. The chains are connected to thermal reservoirs at different temperatures. We analized the existence of different energy transport regimes depending on thermal gradient, size of the system, and strengh and frequency of the time-dependent coupling between chains.The results are obtained by dynamical molecular simulations.

Public Calamity in Brazil: effects of this type of crisis on the local socio-economic dynamics

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The public authorities in the Brazilian municipalities frequently decree emergencies based on their inability to cope with known events within the routines of local administration. On average, 26% of the total Brazilian municipalities have declared emergency each year in the period 2006-2016. When the situation is very unusual and intense, the municipality may decree a state of public calamity, which enables access to exceptional resources, administrative powers and support from higher levels of government. It has occurred 546 times, involving 416 municipalities (7,5% of the total), in the period 2006-2016. The public calamity is officially characterized as a considerable perturbation of the local socio-economic routines. Thus, we raise three hypothesis: (a) the acute crisis should reveal a considerable impact in the normal private and public activities compared to the precedent dynamics; (b) the crisis generates changes in the rhythm of the societal practices, and (c) the period of post-calamity is not a return of the normality, but a new normality, in other words, a new dynamic. This study analysed these three hypotheses focusing the sample of 45 public calamity decrees that occurred in the year of 2011. The socio-economic variables analysed are: (a) revenue from taxation, (b) public debt, and (c) employment levels. The total period of the data analysed was 2006-2016 to distinguish the three intervals relevant to our hypotheses: before the crisis (2006-10), during the crisis (2011) and afterwards (2012-16). We search for causal links between these variables within the data from these 45 cities, in a statistical sense. For that, we have developed the Multithread Causality Toolbox to assess the existence and strength of these causal links by estimating the Transfer Entropy and Causal Mutual Information (CaMI). The findings of this study indicate whether the decrees of public calamity were adequate to the circumstances.

Neuron modeling and transmission of information on the C. elegans network: preliminary results

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The modeling of the topology and behavior of biological nervous structures (*e.g.* the brain) is among the greatest open scientific challenges in the Physics of Complex and Dynamical Systems. The earthworm *C. elegans* is a natural starting point as its nervous connections have been fully determined [1,2]. Additionally, a simple stochastic-dynamical model for neuron firing was proposed by [3] considering the discrete-time history of firing of neighbors and biological features. Properties such as self-organized supercriticality (SOSC) have been shown in such stochastic neuron models [4], which might model conditions such as epilepsy. However, it remains on

debate how the information is transmitted along a neuron network given different conditions [5]. In this work we adopt the *C. elegans* wiring diagram and the Galves-Löcherbach neuron firing model to simulate time-series of neuron firing closer to the expected behavior of a living organism. Conditions for different system states are briefly discussed. Then, we analyze how the information is transmitted or lost through the nodes using the Causality Toolbox [6], which informs the decay of Transfer Entropy and Mutual Information from the signals along the network, among other applications.

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Synchronized cortical activity in auditory perception in canaries

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Songbirds are a well-established animal model to study the principles underlying vocal production, perception and learning. The ‘song system’ is a network of neural nuclei of a songbird’s brain dedicated to these tasks. Telencephalic nucleus HVC is involved in the vocal production and receives highly processed auditory inputs. In asleep or anaesthetized birds, HVC units also respond to a playback of the birds own song (BOS). This auditory response presents a similar firing pattern to the one measured while the bird is singing, suggesting a shared coding mechanism for the two tasks.

In this work, we studied the auditory responses to BOS at HVC in urethane-anaesthetized male adult canaries (*Serinus canaria*). Acute extracellular recordings were conducted at HVC with 32 channel multi-electrode arrays, which provided the possibility to study spatial information together with temporal modulations of the neural activity. The recorded signals allow to recover the slow components due to synaptic currents, commonly referred to as LFP (<300 Hz) as well as the spiking components (>500 Hz). We found that the LFPs at HVC present rhythmic oscillations, locked to the syllabic rate of different song phrases. For a specific syllable type, we found that LFP can be related to instances of synchronous firing of multiple neurons in the recording. This experimental result is in accordance with a previously developed model for song production. This study could provide a new perspective on the study of the neural coding of auditory processing of song and its link to vocal behavior in songbirds.

From molecular dynamics to fluctuating hydrodynamic theory in anharmonic chains

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Recently we studied numerically the correlations among longitudinal and transversal vibrational modes for chains and nanoribbons. We analyzed how these couplings affect the heat transport along them. Theoretically other authors applied fluctuating hydrodynamics, usually used for fluids, to study heat current correlations in anharmonic chains vibrating in 1D. Here we extend this formalism to chains vibrating in 3D subject to an external tension, which are more realistic models for e.g. polymer chains. Elongation, momentum and energy can be considered as seven conserved local fields. In this approach the correlations between these fields can be decoupled to linear order, which results in two longitudinal sound modes, four transversal sound modes and one heat mode. We obtain analytically the velocity of propagation of sound modes. Our control parameters are temperature and tension. Going to second orden in this expansion, the theory allows to compute the spatio-temporal correlations between these modes which are related to the thermal transport properties. We compare theoretical results with molecular dynamics simulations for long chains.

Hyperbolic manifolds and effective stability domains in the Restricted Three-Body Problem

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The invariant solutions of a mathematical model are fundamental to understand and control the evolution of its general solutions. In this context, the hyperbolic invariant manifolds of the Restricted Three-Body Problem (RTBP) are the backbone that allows several applications in Astrodynamics and Astronautics. In recent years, these special solutions have been employed to design trajectories for modern space missions such as Genesis, Hiten, Artemis, and many others. Moreover, they have provided preliminary dynamical models for the motion of natural celestial bodies such as the Trojan asteroids in the Sun-Jupiter system. In particular, codimension-one manifolds play an important role in defining sharp stability boundaries around the triangular equilibrium points, L_4 and L_5, of the RTBP. In this work, we investigate domains of effective stability around these equilibrium points, focusing in the Sun-Earth and the Earth-Moon systems. The ultimate goal is to exploit the applicability of those domains in the context of asteroid capture.

Percolative study of neuronal cell cultures by means of complex network theory.

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The brain is a complex system composed of 14,000 million neurons, approximately, which makes its study difficult. Despite being a complex task, there are currently some experimental and theoretical approaches to address the local interpretation of independent sections of the brain total. Our study is based on the research on percolation in living neural networks carried out by Jordi et al, who start from different experimental procedures analyzing neuronal cultures derived from rat hippocampus. In the analysis, they chemically disturb the synaptic processes of the network destroying its structure, specifically the links between nodes of the complex network model. The research on percolation in neural networks, study the dynamics of the process and based on the theoretical model of complex networks, analyze the reconnection of the nodes with a probability dependent on the length of the Euclidean link between them. Because the damage to the brain, specifically in the networks of neurons, can occur not only at the level of rupture of the connections preventing the synapse but also at the level of the death of neurons. It is relevant to study the processes of percolation in networks of neurons taking into account the annihilation of nodes in the complex network model. We study the theoretical model in a spatially restricted neural network, virtually attacking the nodes of the network. In a percolative process, we eliminate nodes, numerically study the dynamics of the network in the process and perform an analysis of the relationship between the size of the cluster and the probability of percolation. In the percolative study of neural networks we find the threshold of percolation which we relate to the resilience of the network, in the face of random failures to its nodes.

Spatio-temporal intermittency in patterns with translational coupling

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The phenomenon of intermittency consists in the non-regular intercalation of ordered or laminar periods with apparently disordered or chaotic periods in a dynamic system, if this also happens in the spatial dimension of an extended system, we talk about spatio-temporal intermittency. Motivated by the study of translational coupling in a liquid-crystal optical valve with retroinjection [1], we study the phenomenon of spatio-temporal intermittency through the Swift-Hohenberg model with translational coupling:

$$\partial_t u = \varepsilon \tilde{u} - \tilde{u}^3 - \nu \partial_x^2 u - \partial_x^4 u, \tag{1}$$

$$\tilde{u}(x,t) = u(x+L,t) \tag{2}$$

This equation, in its simplest form, is known to form patterns. However, when the L parameter is introduced, we found regions in the parameter space where an intermittent behaviour is observed. Using amplitude equations it can be shown that, near the region of the parameter space where the null solution loses stability through an Andronov-Hopf bifurcation, the envelope of the order parameter $u(x,t)$ can be described by a complex Ginzburg-Landau equation:

$$\partial_t A = A - (b_3 + i)|A|^2 A - (1 - ib_1)\partial_x^2 A, \tag{3}$$

$$b_1 = b_1(\varepsilon, L, \nu), \quad b_3 = b_3(\varepsilon, L, \nu) \tag{4}$$

This equation is known to have multiple phenomena such as phase turbulence, defect turbulence, bichaos and spatio-temporal intermittency [2]. There exists a region in the parameter space where plane wave solutions are stable, however, the sudden appearance of other localized structures gives account for the phenomenon of intermittency. We propose to characterize the transition mechanism from the non-chaotic phase to the intermittent one.

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Vortex Nucleation in Nematic Liquid Crystals

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Liquid Crystals are materials that can be found in multiple applications we use every day, like cellphones, televisions and computers. This theoretical research is based in the experiments that can be made with thin layers of liquid crystals with negative anisotropy and homeotropic anchoring. When the system is put through a sufficiently strong enough electric field it forms vortices which presents rich nonlinear-dynamics. This has been studied with the help of an amplitude equation, corresponding to the anisotropic Ginzburg-Landau equation [1]:

$$\partial_t A = \mu A - |A|^2 A + \nabla^2 A + \delta \partial_{\eta\eta} \bar{A}$$

where $A(x, y, t) = u(x, y, t) + iv(x, y, t)$ and $\partial_\eta = \partial_x + i\partial_y$.

Despite that the anisotropic Ginzburg-Landau equation describes correctly the dynamics of already created vortices. It has been seen that the nucleation mechanisms shown in numerical simulations do not match experimental observations. This drives the research's main objective, which is to study the creation of vortices in liquid crystals by means of the Ginzburg-Landau equation.

Mathematically, vortices are defined as a phase singularity in the amplitude parameter A and they can be characterized by their topological charge N [2]. This last property is used to determine the existence of vortices in numerical simulations, which grants the possibility of conducting a detailed study of their nature.

Doing numerical simulations of the anisotropic Ginzbug-Landau equation with additive white noise. The role played by parameters μ, δ and the noise intensity play has been studied. Carrying out an statistical analysis of the number of vortices created, it has been found that this value changes notably when the values of previously mentioned parameters are modified.

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Macroscopic description of neural ensembles

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Neurons can be thought of as highly non-linear dynamic units whose main characteristic is their excitability. In a nervous system, thousands of neurons interact, generating activation patterns that define different functions in the individual. In many cases, the ultimate output of a nervous system involves the control of a macroscopic biomechanical device, acting as an intermediary between the individual and the environment. The study of neural populations can then be framed within the open question of how to build a statistical dynamics for out-of-equilibrium ensemble of units.

In recent years, the study of this kind of systems has largely benefited from new analytical techniques. These techniques allow to express the dynamics of certain macroscopic observables in large ensembles of coupled oscillators as a reduced set of ordinary differential equations. This makes it possible to build low-dimensional models for neural systems from "first principles". One of the biggest challenges in this kind of modeling is to be able to link the analytical observable for which the dynamic equations are obtained, usually the order parameter, with some measurable biological quantity of the system.

In this presentation I will comment on some of the work done in our laboratory in this direction. We were able to write macroscopic models in terms of firing rates and the total synaptic currents involved. We further reported experimental data suggesting that, in certain conditions, the total synaptic current, as defined in our models, provides a good estimate of the Local Field Potential (LFP). We also study the response of such systems to an external stimulus, and compare their behavior with widely used, heuristically constructed, empirical models.

We believe that the introduction of measurable macroscopic variables, such as the LFP, suggest a path to build a bridge between experimental data and low-dimensional models for neural populations.

Birdsong synthesis using dynamical modelling of the biomechanical periphery

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Song production in oscine birds is an example of a complex behavior emerging from the interaction between the central nervous system and the biomechanical periphery. It requires a precise and simultaneous control of the respiratory system and a set of muscles that innervate the syrinx (the avian vocal apparatus) and determine its configuration and dynamics. Sound is produced when the airflow passing through the syrinx is modulated by the vibrations of two pairs of labia, located at the junction of each of the bronchi and trachea. In particular, the syringealis ventralis (vS) muscle is involved in controlling the tension of the labia and thus affects the fundamental frequency of sound. However, the relationship between the activity of this muscle and the fundamental frequency has been shown to be complex and species-dependent.

In this work we introduce a model of the dynamics of the vS muscle and the syringeal labia. Using the electromyographic activity of the muscle as input, we show that the model is capable of reproducing the frequency modulation of the song. In addition, we propose a set of criteria that, based on the activity of this same muscle, are able to determine with a precision of over 70%, in which moments singing takes place and in which moments the bird is silent. This allows us, using models previously presented in the literature, to obtain synthetic zebra finch songs from the activity of this one muscle.

Since this muscle has recently been shown to display replay patterns of activity during sleep, peripheral activity has become a window into the study of dreams. The models presented here are therefore framed in an effort to interpret behaviorally these activation patterns or, in other words, to listen to birds' dreams.

Intermittent dissipation on fractal regions: the effect of non-localty

Jaime Clark, Juan Alejandro Valdivia and Felipe Torres
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In the past few years there has been a renewed interest about intermittent dynamics and complex patterns, and in particular about the concept of Self-Organization (SO) [1] but under more realistic microphysical process than in the original presentation. In these systems, minor disturbances may lead to events called avalanches that can be produced in a wide range of scales. Furthermore, these events display fractal structure and power laws in their dynamics.

One such system is electric discharges [2] where the dissipation occur in fractal regions and display power laws in parameters like current, charge, etc. The canonical model for SOC is the sandpile [1], which is governed by local interactions given by the difference of heights between neighbors. However, in the case of electric discharges, they are ruled by non-local effects due to the charges.

In particular, we will study the fractal and intermittent dissipation in electrical discharges due to these non-local effects and to characterize their dynamics.

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Faraday patterns with heterogeneous localized injection in a water cell

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Patterns are ubiquitous in nature, e.g., desert dunes, cloud patterns, zebra stripes and more. A classic example of an out-of-equilibrium system in which an extended pattern emerges under spatially uniform external forcing is Faraday patterns. Those patterns arise through a subharmonic resonance in a forced system, such as fluids, magnetic and mechanical systems.

Theoretically, the Faraday patterns bifurcation with uniform injection is supercritical. However, a characterization of the bifurcation type in systems with heterogeneous injection is still an unexplored area. In the current work, we will show an experimental setup of a quasi-unidimensional water cell subject to a localized injection of energy. This system allows controlling the injection area as well as the frequency and amplitude of the forcing. Under this controlled conditions, we characterize Faraday patterns experimentally. We obtain the dynamics and bifurcation diagram of Faraday patterns under localized forcing. The preliminary results show that the system maintains the supercritical nature of the bifurcation as expected.

Stability analysis of sine-Gordon bubblelike structures in inhomogeneous systems

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In this work, we investigate analytically and numerically the stability of bubble-like solitons perturbated by a localized force. As these solutions to the 2D sine-Gordon model are unstable for zero external force, we start by finding the non-homogeneous external perturbation that stabilizes these structures. The linear stability analysis leads to a Schrdinger-like equation with a modified Pschl-Teller potential, which can be solved exactly. Numerical simulations show how shape mode instabilities are induced. Applications in the control of bubble-fluxons in Josephson junctions are discussed.

Thursday Session.

Front propagation in forced medium

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Macroscopic systems subjected to injection and dissipation of energy exhibit complex collective phenomena; for example pattern formation [1], chaos and space temporal chaos [2], turbulence [3], among others. Systems that exhibit this type of behavior are called non-equilibrium systems and are described by nonlinear partial derivative equations. It is important to note that this type of systems, in general, does not have a free energy, therefore, the dynamics are not characterized by minimizing a functional, that is, the system is non-variational [4]. One of the main characteristics of nonlinear equations is to present coexistence of equilibrium states. Depending on the initial conditions or by modifying control parameters or due to inherent fluctuations (noise), systems out of equilibrium can show domains with different equilibrium states [5]. The union of these different equilibria is known as fronts (also as non-linear waves or domain wall, depending on the physical system being studied). Fires are every day and relevant example in our daily life. In this case, the burned and unburned region correspond to the equilibrium states, and the location of the flame accounts for the position or interface of the front. In this work we study the possibility of controlling the speed with which a front propagates (between stable and unstable state), using periodic external spatial forcings. The experimental part of this study consists of a liquid-crystal optical valve with retro-injection (see figure 1), in which fronts between molecular configurations or stable and unstable phases of liquid crystals can be generated and studied in a controlled manner, such as it is also possible to externally force the system and observe the non-variational effects in the fronts. For this system, we propose a non-linear equation with cubic and quintic terms, in addition to the term that models the pretilt of the liquid crystal molecules. Analytical calculations and numerical simulations show good agreement.

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Nasal respiration entrains neocortical long-range gamma coherence during cat wakefulness

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Recent studies have shown that slow electro-cortical potentials in paleocortex and neocortex of rodents and humans phase lock with nasal respiration. In these areas high frequency activity (gamma; 30-100 Hz) is also coupled to the respiratory cycle in a phenomenon called "cross frequency coupling"; One hypothesis is that this interaction has a role in integrating distributed network activity. In a similar way, inter-cortical interactions at gamma frequency has been also hypothesized as an integration mechanism for cognitive functions. Specifically, it is thought that these oscillations generate temporary opportunities for communication and integration of the distributed neural activity necessary for cognitive processes including conscious perception. The aim of the present study is to explore if respiration entrains cortico-cortical interactions at the gamma frequency. Six chronically prepared adult cats were employed in this study. Electrocorticogram from several neocortical areas and olfactory bulb (OB), nuchal electromyogram, electrooculogram, lateral geniculate nucleus electrogram as well as respiratory flux and movements were recorded during wakefulness (W) and sleep. We observed that slow cortical respiratory potential is present in several areas of the neocortex and the OB during W. These slow oscillations are independent of muscular activity, because are maintained during cataplexy induced by carbachol microinjection into the nucleus pontis oralis. We also found cross frequency coupling between the respiratory phase and the amplitude of the gamma activity in all recorded areas. Finally, we found that respiratory phase modulates the inter-cortical gamma coherence between neocortical pairs of electrodes during W. However, during NREM and REM sleep, breathing was unable to entrain the oscillatory activity neither in the OB nor in the neocortex. These results suggest a single unified phenomenon involving cross frequency coupling and long-range gamma coherence across the neocortex. This fact could be related to a temporal binding process necessary for unified conscious perception during W.
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Role of fluctuations and correlation functions in epidemic models

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Deterministic compartmental equations are mathematical tools to assess the spreading of communicable diseases in large populations. They can be readily applied to empirical data and they provide a clear methodology to extract relevant epidemiological parameters. However, compartmental equations neglect fluctuations and correlation functions which leads to disagreements with empirical and simulated

data for small populations. Here, we investigate the role of fluctuations and correlation functions in the SIS agent-based model. We find corrections to the traditional compartmental equation due to fluctuations and correlations, providing accurate estimates of epidemiological parameters in finite populations. Our findings also provide a new equation for the special case of Gaussian fluctuations. We derive canonical transformations and interpret the results using the formalism of Hamilton equations, offering new insights for disease spreading.

Wandering chimera-like states in continuous media

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In recent years the so-called chimera states, defined by patterns having coexistence of coherent and incoherent dynamics has attracted the attention in several scientific disciplines. Whereas most of the previous studies focused their attention in locating chimera states in discrete systems composed by coupled oscillators, a few are known about their spatial dynamical properties and less about the appearance of such kind of states in continuous space systems, where the chaoticon as a chimera-like state is one example. In this work, we report chimera-like states in continuous media and study their spatial dynamics. In particular, we show the emergence of a spatial wandering chimera-like states in the nonvariational real Swift-Hohenberg model in the strong nonvariational regime. Then, we characterize its behavior by using several methods from spatial extended dynamical systems and statistics. Finally, we explore the nonvariational parameter to follow the route from motionless to traveling behavior and intent to explain the mechanism behind this transition.

Topological transitions out of equilibrium

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The matter in thermodynamics equilibrium, in quasi two spacial dimensions, as temperature decrease, it can exhibit exotic states of matter, it corresponds to topological transitions associated to emergency of pairs vortexes (BerezinskiiKosterlitzThouless transition). This type of phenomena has been observed in different contexts such as Josephson junctions, superconductor thin films, among others, which allowed that KosterlitzThouless obtaining the Nobel prize in the year 2016.
We are interested in study this phenomena in out equilibrium systems systems with temporarily modulated parameters, for this, we have considered a thin film of nematic liquid crystal with negative electric constant and with homeotropic anchoring. An oscillatory voltage is applied to nematic liquid crystal film, the balance between electric force and elastic force of the molecules allow the creations of topological defects called vortexes. In a range of frequency between 500[μHz] and 0.5[Hz], the system described previously exhibit different transitions of topological phases in which pairs and networks of vortexes emerge, among other topological phenomena.

Dynamics properties for a one-dimensional impact system with two periodically vibrating walls under scaling analysis

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We investigate the dynamics of a system composed of a particle suffering impacts between two heavy periodically vibrating walls. An original, nonlinear area preserving mapping is obtained. The control parameters of amplitude of perturbation and frequency of oscillation play an important role in the phase space, shaping the portion of chaotic seas, position of invariant curves and the amount of KAM islands. The study of the behavior of the root mean square velocity was made via analytical description and numerical simulations. We proposed scaling arguments to describe its dynamics and our results show remarkably good agreement between the theory and the simulations concerning a scaling invariance with respect to the control parameters. Also, an analysis of the diffusion coefficient confirms the validity of the scaling invariance, giving robustness to our modeling.

[1] A. L. P. Livorati, Phys. Lett. A, **381**, 2214 (2017).

A robust barrier used to improve particle acceleration in plasmas

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We investigate the dynamics of a low density beam composed by relativistic particles interacting with a uniform magnetic field and a stationary electrostatic wave. According to the wave parameters, the resonant islands used for particle acceleration acquire a triangular shape. In this case, the initial energy of particles is close to their rest energy, whereas their final energy is maximum. However, this optimum condition for particle acceleration from low initial energies can only be achieved for limited values of the wave amplitude. When the wave amplitude is low, resonant islands are not triangular shaped, and particle acceleration from rest energy is not possible. For high amplitude waves, the system becomes chaotic, and the islands used for particle acceleration are destroyed. In this work, we add a robust barrier, generated by an external perturbation, to the system with the purpose of improving particle acceleration. We calculate analytically the allowed positions of the barrier in phase space as a function of the wave parameters. We also determine the best position of the barrier in order to improve particle acceleration from low initial energies. We show that the perturbing robust barrier considerably enlarges the wave amplitude interval for which the optimum condition for particle acceleration is achieved. For low amplitude waves, the barrier reduces the initial energy of particles to their rest energy. For high amplitude waves, the barrier controls chaos and restores the acceleration process. In both cases, the barrier also increases the final energy of particles. Therefore, we show that the addition of a properly located

perturbing robust barrier to the system is a very efficient method to improve particle acceleration. The procedure we present, addition of a perturbing robust barrier, can similarly be applied to other systems to alter resonant islands, control chaos, and, consequently, improve applications of interest.

Multiplexity of Crime Network Using Public Security Intelligence Data

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Studying networked criminals is challenging as it allows new responses to the demand for Public Safety. Research in the area has focused on hierarchy, characters, and violence in criminal organizations. The approach used so far in the main studies treated criminal networks as one-dimensional networks of criminal activity, where crime is defined by its position in relation to the elements of the network, but criminal networks do not refer only to the criminal group but comprise inter-relationships between criminal networks that can be identified.

The use of multiplex networks in criminal networks makes it possible to identify the groups that participate simultaneously in different crimes, to identify the people who participate in various crimes with different groups, and to study the similarities of these groups in the sense of organization. Network multiplexing has a strategic and relevant character to identify interactions that include some degree of risk, such as crime networks, that exist and operate outside the formal legal system.

The development of a set of tools for metrics, algorithms and theoretical methods, directed to this type of application, was one of the challenges of this work. Using these new perspectives, it was possible to identify the most vulnerable points of crime networks, and to implement actions for their dismantling. This work is a pioneer in using the concept of multiplex networks to identify criminal networks.

Influence of non-translational degrees of freedom on Brownian motion

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The coefficient of restitution representing the non-translational degrees of freedom of an emulsion Brownian drop was included in the Fluctuation - Dissipation Theorem by using a finite collision time. A schematic model is proposed where the two dynamic regimes obtained from the Langevin equation now include an intermediate regime. The inclusion of this time, as well as the dissipation of part of the energy coming from the fluctuation through those degrees of freedom represented by the coefficient of restitution, modify the mean square displacement.

Dynamics of Interfaces in a Vertically Vibrated Granular System

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Universidad de Chile, Chile.

This work aims to study the dynamics observed in a parametrically vibrated granular bed. We forced the system by mean of vertical vibration in a range of frequencies. We observe the coexistence of different states at the same time separated by an interface characterized by the emission of a "flaming" nonlinear waves with a rich dynamics. These states evolve as the frequency varies leading to convective rolls, subharmonic waves and fluidization state. The bifurcation diagram was characterized. Based on a phenomenological model the appearance of the flaming interface is described.

Trajectory entropy production in a model for active particles

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Universidad de Chile, Chile.

Active matter systems are out of thermal equilibrium, its dynamics are usually described by a Langevin-Like equation, with an extra noise (Active Brownian Particles, ABP) or replacing the white noise for a correlated noise (Active-Ornstein-Uhlenbeck Particles, AOUP). We propose a model, that contains both ABP and OUAP, and In the framework of stochastic thermodynamics, we describe the entropy production on a trajectory. In our approach, the particle is connected to two heat reservoirs, and also,it allows to recover previous results and use Linear Response Theory to propose an experimental test.

Applications of autocorrelation functions in the spreading of multidrug resistant tuberculosis

Ana Carolina Pedrosa Monteiro, Gilberto Nakamura, Luiz Henrique Arroyo and Ricardo Alexandre Arcêncio
University of São Paulo, Brazil.

Tuberculosis is a communicable disease caused by *Mycobacterium tuberculosis*. Improper or incomplete treatments of tuberculosis are the leading causes of a stronger variant of the disease, the multidrug resistant tuberculosis. Even though new treatments are available, they are often expensive, carry severe side effects, and are longer than regular treatments, increasing the global burden of tuberculosis. Despite significant advances in predictive models for tuberculosis spreading, most results neglect autocorrelations, which impacts predictions concerning multidrug resistant strains. Here, we propose a simplified stochastic process for drug-sensitive and drug-resistant tuberculosis with five health states. We write the corresponding transition matrix

and perform Monte Carlo simulations. The time evolution for each health state and their autocorrelations functions are evaluated. Our numerical findings show that the autocorrelation reaches its maximum value when the density of patients infected with multidrug resistant tuberculosis lies around half of its steady state density. In addition, the normalized autocorrelation decay rate for multidrug resistant tuberculosis depends solely on the difference between its infection and recovery rates.

When atypical Conditional Lyapunov Exponents become the typical and physically relevant ones

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Lyapunov Exponents (LEs) are fundamental to understand the global dynamics of complex networks. For typical initial conditions and under very general hypothesis, Oseledec's theorem guarantees that these exponents exist, and therefore can be obtained for a large set of nonlinear systems. They are also the ones that one should expect to obtain by understanding how an initial volume of initial conditions is modified by the application of the dynamics. They are indeed the"physical" exponents. There are also the "atypical" Lyapunov Exponents, such as the one this work is interested, the Lyapunov Exponents of the synchronization manifold and their transversal directions, here referred as the Conditional Lyapunov Exponents (CLEs). Though atypical in the physical sense mentioned before, they are fundamental to understand how synchronization and collective behaviour emerge in complex networks. They are particularly interesting for technological systems that rely on synchronous behaviour, and fundamentally, they are trivial to be calculated, as compared to the complexities involved in the calculation of the LEs. In this work, we will examine a case of nonlinear systems with constant Jacobian for which these exponents, the LEs and the CLEs are equal, allowing a trivial calculation. We will also show when they are not the same. Though typically one should expect them to diverge, since they are calculated in different parts of the phase space, we show that their divergence for systems with constant Jacobian is due to a fundamental nature in the methods for their calculation. Under some conditions of the graph, the standard method (QR decomposition - or analogously using the Gram-Schimidt) as well as any other method that relies on it, will provide unexpectedly the CLEs, not the typical physical LEs.

Hamiltonian immiscible chaos

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The phase space of Hamiltonian systems can be subdivided in regions with regular and chaotic dynamics. Typically, chaotic regions are bounded by regular tori and and chaotic transport is largely controlled by the invariant manifolds of periodic saddles, however, in more exceptional situations a transport barrier separating two chaotic regions may develop from a non-twist bifurcation. In this work we present a novel situation where a family of transport barriers emerge without violation of the twist condition and leads to a sequence of immiscible chaotic regions in phase space. The nature of the barriers is discussed and the case is illustrated by a simple annular billiard.

Exact dynamical solution of the Kuramoto Model for finite networks of identical oscillators

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We study the Kuramoto–Sakaguchi (KS) model composed by any 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.

Algorithmic complexity in chaotic lasers with extreme events

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Determining whether a 'noisy' signal is random or chaotic from experimental time series is a fundamental problem. Chaos is deterministic and, to some extent, predictable and controllable. Random signal, on the other hand, is not predictable and therefore uncontrollable. Proving that a system is chaotic implies finding the underlying attractor and positive Lyapunov exponents. This task is, in general, complicated in addition to requiring a huge amount of experimental data. In the 1960s, Kolmogorov developed the concept of algorithmic complexity. It basically tries to answer the question: What is a random object? The Kolmogorov complexity of an object x is the length of the shortest description of x. In this way the only possible description of a random object is the explicit enumeration of each of its components, and it has maximum complexity. A periodic signal, at the other end, will have minimal complexity, while chaotic signals have intermediate complexity. In

this poster we present the results of the computation of the algorithmic complexity or Kolmogorov complexity through the Lempel - Ziv algorithm, from experimental time series of three different lasers, all with chaotic behaviors with extreme events but of different etiology. It is shown that in all cases the Kolmogorov complexity adequately describes chaotic behaviors with and without extreme events. Given its simplicity of calculation, it becomes an effective tool for diagnosing chaotic behaviors that can also be easily incorporated into real-time chaos control schemes.

Decreased EEG complexity distinguishes sleep from wakefulness

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Permutation Entropy (PE) is a complexity measure that has been shown to discriminate 'conscious' and 'unconscious' states. For example, in humans under general anaesthesia, PE can discriminate different sleep stages where consciousness is minimal or altered. Since the rat has visually distinguishable sleep stages in electroencephalographic (EEG) recordings, we use rats to quantify critically the distinctions arising between different sleep stages using the PE values of intra-craneal EEG recordings. Our aim is to show that PE can be used to obtain sleep staging information automatically, replacing the currently used visual characterization. Our results show that EEG's complexity is maximal during wakefulness and it decreases during sleep, meaning that when the animal is awake it shows unpredictable EEGs with rapid changes that simplify while asleep. We find that these results are cortical-area independent, pointing towards a global cortical pattern that is quantified robustly and automatically by the PE. However, depending on the sampling frequency (SF) being considered, we find that the PE for rapid-eye-movement (REM) and non-REM (NREM) sleep interchange values. In particular, using high SF ($1024\,Hz$), we obtain higher PE values for NREM sleep than for REM sleep. The opposite happens when decreasing the SF more than twofold ($< 512\,Hz$). Consequently, we show that the PE of a signal depends on the SF used, but also, that changes in the SF provide distinctive information about the signal's frequency content. This points to a universal phenomenon that needs to be taken into consideration whenever using PE to classify time-series complexity.

The dispersionless integrable systems and related conformal structure generating equations of mathematical physics

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Based on the vector fields on the complexified torus and the related Lie-algebraic structures, we devise an approach to constructing multidimensional dispersionless integrable systems, describing conformal structure generating equations of mathematical physics

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Firing patterns of synchronisation in a neuronal network based on cortico-cortical connections of human brain

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We investigate the influence of synaptic coupling in synchronised firing patterns. We build a neuronal network according to the cortico-cortical connections of the human brain. Each brain area is represented by a random network composed of coupled adaptive exponential integrate-and-fire neurons. To identify the firing patterns of spike and burst we use the coefficient of variation of the inter-spike interval. To study synchronisation, we consider the time average of the Kuramoto order parameter. Depending on the excitatory and inhibitory synaptic coupling, the brain can present desynchronised spike, and synchronised spike or burst. Abnormal synchronisation is related to brain diseases such as epilepsy and Parkinson. In our network, we observe a rich-club organisation on the connections of the brain regions which is characterised by a tendency of higher linked areas to be connected between themselves. For weak coupling, the entire network presents desynchronised firing patterns. Increasing the excitatory synaptic coupling we observe that the most connected brain areas changes from spike to burst synchronisation before than other regions. We show that the rich-club organisation plays an important role in the synchronisation transition of the human brain.

Chimera states in neuronal network

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Neuronal systems can be modelled through of complex networks in several different scenarios. Newly, it has been verified that the neuronal systems can simultaneously exhibit one coherent and other incoherent spatial domain, known simply in literature as chimera states. In some animals this states are due conflict between wakefulness and sleep owing dangers of the environment to which they are constantly exposed. Besides that, several types of brain diseases of strong relevance: epileptic, schizophrenia, Parkinson, etc., have coexistence characteristics of states. In this work, we show the existence of chimera states in Hindmarsh-Rose model where the connectivity matrix is based on the experimental cat cortex due to Jack W. Scannell. The cat cerebral cortex can be divided in sixty-five cortical areas subdivided into four cognitive blocks: auditory, somatosensory-motor, frontolimbic and visual. We use excitatory chemical coupling for simulate the synapses between neurons of the network. Thus, we obtained the presence of two kinds of chimera-like states in the cat cerebral cortex: bursting chimera-like state (BC) with desynchronised bursts, and spiking chimera-like state (SC) with desynchronised spikes. Moreover, we adding a random term in the external current for study the behavior of the network about the noise effect. This way, we show that SC is less robust to noise than BC.

Electrophysiological characterization of dorsal and median raphe neurons

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The dorsal (DRN) and median (MnR) raphe are the main serotonergic nuclei and are implicated in sleep and mood regulation. The DRN is mainly serotonergic whereas the MnR is divided in a median mainly serotonergic region, and a paramedian region containing principally GABAergic neurons. In the present study, we examined in urethane-anesthetized rats the basal activity of DRN and MnR neurons and their response to posterolateral hypothalamic (PLH) stimulation, where MCHergic neurons are located. The DRN neurons recorded (n=107) showed different characteristics than MnR neurons (n=154). The action potential duration was significantly larger than the median and paramedian region of the MnR (2.8+/-1.4 ms vs 2.4+/-0.9 and 2.4+/-0.7 ms, respectively, $p < 0.05$). The firing rates were also lower for DRN only when compared to the paramedian region (7.8+/-10.2 vs 14.7+/-19.1 Hz; $p < 0.01$). The coefficients of variation were significantly lower compared with both regions of the MnR (0.54+/-0.69 vs 1.0+/-1.4 and 0.9+/-0.7; $p < 0.01$). Rhythmic

neurons were less frequent in the DRN compared to both regions of MnR (31% vs 45% and 51%; $p < 0.01$), whereas the proportion of neurons with burst activity or with a unimodal interval histogram where similar for both nuclei. Electrical stimulation of PLH produced a decrease in the firing rate in 46% of MnR and 26% of DRN neurons tested, whereas an increase in the firing rate in 32% of MnR and 22% of DRN was observed. Strikingly, the inhibited neurons where mostly located in the median region of the MnR whereas the stimulated neurons where located in the paramedian region. To conclude, in this study we characterized the basal activity of the mesopontine raphe neurons as well as their response to PLH stimulation. Our perspective is to explore novel characterization metrics to this purpose.

Neural Network inference: C. Elegans and statistically similar networks.

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The understanding of neural networks has seen major advances in recent decades, specially on their function and connectivity. However, basic aspects remain a mystery, such as the relationship between structural properties and emerging behaviors - even for small systems like the Caenorhabditis Elegans nematode neural network. Here, we critically analyze the limits of inferring the connectivity of synthetic neural systems sharing similar topological properties to the C. Elegans frontal and global neural networks - specifically, size, edge density, randomness, and small worldness. Our systems are composed of pulse-coupled Izhikevich maps in bursting dynamics connected in Erdös-Rényi, Watts-Strogatz, and C. Elegans structural networks. We perform network inference using bi-variate similarity measures from observed time-series (membrane potentials or interspike intervals) and we analyze the effectivity and robustness of the process under different collective behaviors (i.e. under different coupling strengths). Our results show that the inference success rates, for most coupling strengths, are higher in Watts-Strogatz networks than in Erdös-Rényi topologies with similar edge densities. In other words, small-worldness favors network inference. However, success rates in the C. Elegans frontal and global networks have closer values to inference in Erdös-Rényi than in Watts-Strogatz topologies. Moreover, we find better success rates when using membrane potentials instead of interspike intervals as the time-series choice, although robustness is significantly decreased. Namely, there is a trade off between robustness (with interspike intervals) and effectiveness (with membrane potentials) for the inference success rates. These results are relevant to understand better the relationship between topological properties and function in the C. Elegans neural networks, but could also be relevant to design artificial neural networks.

Emergence of catastrophes in competing populations

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A logistic map is a discrete-time simplistic model for a demographic evolution, where the number of individuals in a population at a given state is expressed in terms of the number at the immediately previous state. In particular, this one-dimensional model captures two evolving characteristics: reproduction and starvation. Here, we analyse two coupled logistic maps by means of numerical simulations and experimental realisations, which are based on an electronic implementation of the system. This coupled configuration can be thought as a model for the dynamics of two populations competing or co-operating for resources in a common environment. The experimental realisation of each map is characterised and validated by means of the bifurcation diagram obtained when varying the map's parameter – representing the population's reproduction rate with respect to the environment's carrying capacity. The maps' coupled behaviour is analysed by performing a fine sweep in the coupling parameter, ε – namely, the intensity by which the populations interact among each other is fine tuned. Both, the experimental data, coming from our electronic implementation, and our numerical simulations, allow to confirm the presence of what we call "hysteresis". That is, the system goes through different states when increasing or decreasing the coupling strength. These results can be a warning for the effects that anthropogenic forcing causes on species co-habitation, considering that external changes to the interaction between species can lead to catastrophic outcomes, for example, sudden irreversible state changes or state changes that could take a great effort to restore.

Measuring Chaos in coupled Chua's circuits

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Chaos characterization in a dynamical system is done by specifying invariant quantities, which allow us, for example, to establish the stability of the trajectories, or to establish the geometry and information produced in strange attractors. Particularly useful invariants are the Lyapunov exponents (namely, the average divergence/convergence rates for the trajectories), the entropy (namely, the trajectories unpredictability), and the fractal dimensions (namely, the effective degrees of freedom). In this work, we study experimentally the behaviour of the largest Lyapunov exponent - obtained from time series measurements - in a system of two coupled Chuas circuits as we vary the control parameters. We estimate from these measurements the system's entropy. The experimental results are successfully compared with numerical simulations in the parameter space composed of the coupling strength and parameter mismatch. Moreover, we discuss the possible behaviours emerging from these results for a wide range of parameters, also considering the possible synchronized states.

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