XVI Latin American Workshop on Nonlinear Phenomena

Book of Abstracts

Date: December 28, 2019

Version: 1.1

La Paz, Bolivia 22-26 October

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Organizers

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Contents

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Chapter Introduction

1.1 The Latin American Workshop on Nonlinear Phenomena (LAWNP)

This international conference will be the sixteenth edition of a series that have gathered, biennially over the past 30 years, physicists and other scientists who focus their work on several aspects of nonlinear phenomena. The rapidly growing Latin American community has successfully organized previous conferences in:

- La Serena, Chile (2017)
- Cartagena, Colombia (2015)
- Cordoba Argentina (2013)
- San Luis Potosi, Mexico (2011)
- Buzios, Brazil (2009)
- Arica, Chile (2007)
- Bariloche, Argentina (2005)
- Salvador, Brazil (2003)
- Cocoyoc, Mexico (2001)
- Cordoba, Argentina (1999)
- Canela, Brazil (1997)
- Bariloche, Argentina (1995)
- Mar del Plata, Argentina (1993)
- Santiago, Chile (1990)
- Mar del Plata, Argentina (1988)

The LAWNP has a local organizing committee who benefits from the advice of an international consulting committee.

The LAWNP have been held since 1988 as a forum for the dissemina-

tion of results and discussion of the advances in nonlinear dynamics and complexity science in Latin American and with whole world projection. The topics addressed in these workshops are vast and take into account the inter, multi and transdisciplinary nature of this part of science, including:

- Fluctuations in systems far from thermodynamic equilibrium
- Thermodynamics of irreversible processes
- Dynamics of growth and competition in populations
- Cooperative phenomena
- Reaction-diffusion systems
- Self-organized structures
- Synchronization
- Spatially extended systems and pattern formation
- Neuroscience
- Nonlinear phenomena in biological systems
- Nonequilibrium statistical physics
- Nonlinear fluid dynamics
- Turbulence
- Plasmas
- Complex fluids
- Colloids and granular media
- Nonlinear properties of soft matter
- Classic and quantum chaos
- Instability and bifurcations
- Nonlinear wave propagation, solitons
- Nonlinear optics
- Active matter
- Flocking dynamics
- Nonlinear dynamics of complex systems in the natural and social sciences

- Complex networks and underlying problems: traffic dynamics, spread of rumors and epidemics
- Econophysics and sociophysics
- Control theory and its applications, power-grid networks

The workshops are devoted to the presentation of new results in these areas, to the exchange and discussion of ideas, to the possible establishment of collaborations, to the motivation of students and young researchers in the field, and to the popularization and dissemination of these topics to the society in all its levels.

1.2 The LAWNP in Bolivia

As it might be concluded from the above, the different versions of LAWNP have taken place only in five over the twenty Latin American countries. The latter is undoubtedly due to the advances in nonlinear science and complexity in these countries and also the existence of bigger scientific communities related to such topics. However, various Bolivian scientists have actively participated in some of the LAWNP and somehow they thought about the possibility of holding this event in Bolivia. At the end of the last LAWNP in La Serena, Bolivia has been nominated to organize the next LAWNP what we considered as an invaluable opportunity to show our advances in research and also our capacity to organize such an event, in spite of not having the scientific tradition of the previous LAWNP organizing countries. In recent years Bolivia has experienced an important growth in the research activities related to nonlinearity and complexity, being that since 2001 the so-called Group of Complex Systems, initially issued in the Department of Physics, has disseminated the enthusiasm of doing research in these topics to other Departments of the Faculty of Sciences and of the Universidad Mayor de San Andrés (UMSA) in general. In these 17 years, around 70 publications were generated both

in the Bolivian Journal of Physics and in different international journals. The members of the Group supervised more than 15 bachelor works and 4 master thesis. Currently, there are 4 postgraduate students developing their PhD thesis within the Group. On the other hand, 15 versions of the Bolivian School on Complex Systems have been organized up to now; it is carried out annually with different topics of interest with the participation of invited lecturers mainly from Latin America and Europe. Two international events were also organized in the country corresponding to the first two versions of Nonlinear Dynamics Andean Days.

In view of the precedent history, the realization of the LAWNP in our country represents an important success for the Bolivian scientific community in nonlinear dynamics and complexity. It is a particular honor for the Universidad Mayor de San Andrés and the Escuela Militar de Ingeniería as the main host institution and for Bolivia in general to host this event of great international importance.

Chapter Program

Monday, 21nd October 2019

16:00 18:30 *Welcome Reception and Registration*
EMI Salon "Federico Ramon", near the entrance

Tuesday, 22nd October 2019

08:30	*09:00*	*Registration*	*EMI Entrance*	
09:00	*09:15*	*Inauguration*	*EMI Auditorium*	
09:15	**10:00**	EMI Auditorium	**Theo Geisel**	Temporal fluctuations in musical performances
10:00	**10:30**	EMI Auditorium	**Frank Grossmann**	Coherent state based approaches to quantum dynamics
10:30	*11:00*	*Coffee-break*		

		Room1		Room2		Room3	
11:00	**11:30**	**Marcus Beims**	Weak chaos and finite time Lyapunov exponents	**Elbert Macau**	Characterizing the exceptional 2014 drought eventin Sao Paulo by drought period length	**Christian Moukarzel**	Spontaneous rotation in vibrated packings
11:30	**12:00**	**Juan Diego Urbina**	Semiclassical methods in Fock space	**Raúl Rechtman**	Chaos and phase transitions of a probabilistic cellular automata	**Alejandro Jenkins**	From dissipation-induced instability to the dynamics of engines

12:00	*14:00*	*Lunch*	*Hotel Calacoto*	*for everybody*

		Room1		Room2		Room3	
14:00	**14:30**	**Rene Rojas**	Chimera states in a Duffing oscillators chain	**Rodrigo Soto**	Bacteria driving droplets	**Thomas Dittrich**	Quantum chaos and quantum measurement—paradigms of information production on the smallest scales
14:30	**15:00**	**Rene Medrano**	The role of chaotic transient in synchronization of networked systems	**Zui Oporto**	Mathematical considerations for the determination of a dynamical system for the description of charged massless particles	**Fernando Vera**	Isochronous sets in Invariant Control Systems
15:00	**15:30**	**Jose Francisco Gomes**	Integrable Hierarchies, Solitons and Backlund Defects				
15:30	*16:00*	*Coffee-break*					
16:00	**16:45**	EMI Auditorium	**Marian Wiercigroch**	Grazing Induced Bifurcations: Innocent or Sinister?			
17:30		*From EMI: Go to UMSA*					
18:30	**19:00**	UMSA Paraninfo	Inauguration				
19:00	**19:30**	UMSA Paraninfo	Divulgation talk	**Cristina Masoller**	Analisis de series de datos temporales con aplicaciones interdisciplinarias (al clima, el cerebro y las olas gigantes)		
19:30	**20:15**	UMSA Paraninfo	Divulgation talk	**Maximino Aldana González**	Dinámica unicelular y poblacional de la resistencia a antibióticos en bacterias		
20:30			*Return to EMI*				

Wednesday, 23rd October 2019

08:30	**09:15**	EMI Auditorium	**Cristina Masoller**	Data-driven methods for anticipating dynamical transitions and inferring the connectivity of oscillatory systems
09:15	**10:00**	EMI Auditorium	**Thorsten Poeschel**	Packing of Circular Filamentous Matter

10:00 *10:30* *Coffee-break*

		Room1		**Room2**	
10:30	**11:00**	**Monica Garcia Ñustes**	Rabi-like oscillations in a dissipative system	**Flavio Ghezzi**	Chaos and Hyperchaos of the Tarka - an Andean Musical Instrument
11:00	**11:30**	**Viviana Monje-Galvan**	Molecular interactions in cellular processes, a perspective from simulations	**Carlos L. Pando L.**	Rare Events in Coupled Lasers
11:30	**12:00**	**Hamilton Varela**	Electrocatalytic oscillations on model surfaces	**Rider Jaimes-Reátegui**	Secure transmission of information through coexisting chaotic attractors

12:00 *14:00* *Lunch* *Hotel Calacoto* *for everybody*

	Room1: Astrophysics Symposium		**Room2: Dynamical Systems Symposium**		**Room3: Biological systems**	
14:00-16:00	**14:00-14:50 Miguel A.F. Sanjuan**	Exploring chaos and fractals in binary black holes	**14:00-14:50 Roberto Markarian**	Mathematical Billiards. Results and methods	**14:00-14:40 Maximino Aldana**	Flocking in open space: the role of long-range interactions
	14:50-15:40 Jhon Etiénne Beckman	The resonant structure of galaxy discs	**14:50-15:40 Jeroen Lamb**	Classification of 1D random homeomorphisms up to topological conjugacy	**14:40-15:20 Marcelo Kuperman**	Models and experiments on pedestrian evacuation
	15:40-16:00 Gabriela Conde	Fractal Analysis of a Galaxy Distribution	**15:40-16:00 Jimmy Santamaria**	The Schwarzian derivative and Singer's Theorem	**15:20-16:00 María Fabiana Laguna**	Mathematical models of extinction and coexistence in complex ecological networks

16:00 *16:30* *Coffee-break*

16:30	**17:15**	EMI Auditorium	**Hans Herrmann**	Abrupt epidemic spreading

17:30 *From EMI: Go to Jardin Japones*

18:15 *From Calacoto Hotel: Go to Jardin Japones*

19:00 ***22:00*** *Dinner* *Jardin Japones, Irpavi*

Thursday, 24th October 2019

07:30		*Meeting at the green cable Car station "Irpavi" (near EMI) to go to the Cable-car auditorium*		
09:00	**09:30**	Faro Murillo auditorium	**Imre M.Jánosi**	Bulbous plants precisely measure the length of winter and adjust flowering dates
09:30	**10:00**	Faro Murillo auditorium	**Jason Gallas**	Nested sequences of arithmetic progressions in a discrete neuron model
10:00	**10:30**	Faro Murillo auditorium	**Tomasz Kapitaniak**	Traveling amplitude death in coupled pendula
10:30	11:00	Coffee-break		
11:00		*Touristic tour*	*Will be take in charge by guides directly from Faro Murillo Station* *Time of return according to the tour*	

Friday, 25th October 2019

08:30	**09:15**	EMI Auditorium	**Antonio Celani**	Learning to soar like a bird
09:15	**10:00**	EMI Auditorium	**Jeroen Lamb**	Bifurcations in random dynamical systems
10:00	*10:30*	*Coffee-break*		
10:30	**11:00**	EMI Auditorium	**Edson Denis Leonel**	Chaotic diffusion for a family of area preserving mappings
11:00	**11:30**	EMI Auditorium	**Miguel A.F. Sanjuan**	Binary Black Hole Shadows: Chaos in General Relativity
11:30	**12:00**	EMI Auditorium	**Felipe Barra**	Quantum thermodynamics with repeated interaction and collisional models

12:00 *14:00* *Lunch* *Hotel Calacoto* *for everybody*

		Room1		**Room2**		**Room3**	
14:00	**14:30**	**Pablo Balenzuela**	Quantifying time-dependent Media Agenda and Public Opinion by topic modeling	**Marcos Gomes E da Luz**	Construction of Distinct Discrete Time Scattering Quantum Walk Formulations on the Honeycomb Lattice	**Celia Anteneodo**	Spatial organization and survival of single species populations
14:30	**15:00**	**Jose Daniel Muñoz**	Cellular Automata for car traffic and Lattice Boltzmann models for curved coordinates: the taste of discreteness	**Eric Campos-Cantón**	Itinerary synchronization between coexistence of chaotic attractors	**Tim Herpich**	Thermodynamics of nonequilibrium phase transitions in driven Potts models
15:00	**15:30**	**Victor Dossetti**	Self-organization in one-dimensional systems of interacting Brownian particles: synchronous vs asynchronous updates	**Rok Cestnik**	Inferring the dynamics of oscillatory systems using recurrent neural networks	**Karin Alfaro-Bittner**	Propagation of wet oxidation front in aluminum-rich layers: theory and experiments
15:30	**15:55**	**María Fabiana Laguna**	"¿Es necesario hablar de género en Ciencia?" (in spanish)	**Boris Atenas**	Vlasov dynamic solutions in a model with long range interactions	**Miguel A.F. Sanjuan**	Introducción al caos determinista y el problema de los 3 cuerpos (in spanish)

15:55 **16:30** EMI Auditorium **Poster presentation: 1min per poster**

16:30 *18:30* *EMI Hall* ***Coffee-break, cultural event and poster session***

18:00 *EMI Hall* Prize announcement for the 3 best posters

18:30 *EMI Hall* Cultural event with autoctonous music

Saturday, 26th October 2019

		Room1		Room2		Room3	
08:30	**09:00**	**Gabriela Conde Saavedra**	Route to oscillation death in mutually coupled light-controlled oscillators	**Sabrina Camargo**	Nonstationarities of physiological time series: detection and analysis	**Veronica Subieta**	Characterization of a decision taking discrete social model based on complex networks
09:00	**09:30**	**G. Marcelo Ramírez-Ávila**	A modeling approach for explaining the fireflies' synchronous behavior	**Stéphanie Depickère**	Aggregation and geotaxis in Chagas disease vectors	**Milena Páez-Silva**	Localized Faraday patterns under heterogeneous parametric excitation
09:30	**10:00**	**Roy Bustos Espinoza**	Characterization of the synchronization of 3 mobile oscillators using as a coupling model that of the restricted three-body problem	**Miguel Vizcardo Cornejo**	Detection of dysautonomy and enervation in patients with Chagas disease using HRV and entropy	**Gregorio González-Cortés**	Extended stable equilibrium invaded by an unstable one
10:00	**10:30**	**Rok Cestnik**	Inferring the dynamics of oscillatory systems using recurrent neural networks			**Sorge Oporto Almaraz**	Triggering and confinement effect of 1D to 3D chaotic solitons by the interplay of periodic spatio-temporal fields
10:30	*11:00*	*Coffee-break*					
11:00	**11:45**	EMI Auditorium	**Pedro Lind**	Aerodynamics and Percolation			
11:45	**12:30**	EMI Auditorium	**ICTP Meeting, election of the LAWNP 2021 place**				
12:30	*13:00*	*Closure*					

List of posters

Daniel Acuña	Topological Elastic Metamaterials
Andrey Alcala, Zui Oporto	Non-Linear Galilean Electrodynamics
Jhon J. Balaguera Amado, Fernando Naranjo M, Diana Carolina Latorre V	Network properties of written Spanish human language: “La Hojarasca” by Gabriel Garcia Marquez
Cleber C. Bueno, André L. P. Livorati, Edson D. Leonel, Juliano A. de Oliveira	Dynamical properties in the dissipative standard mapping
Roy O. E. Bustos-Espinoza, G. M. Ramírez-Ávila	A new seed found in an integer sequence
Luis Cabezas Tito, Rodolfo Gutierrez-Barrón, Roy O. E. Bustos Espinoza, G. Marcelo Ramírez-Ávila	Experimental study of synchronization in coupled electronically equivalent logistic maps forming motifs
Winder Canezo-Gómez, G. Rodrigo, G. Marcelo Ramírez-Ávila	Cancerous cells population dynamics analysis using a model with radiosensitivity
Alicia G. Castro Montes, Mónica A. García-Ñustes, Juan F. Marín	Dynamics of bubble-like fluxons under the action of localized forces
Sami Céspedes, Zui Oporto	An approach to FLRW-cosmology from a dynamical system perspective
Mario Rene Cordero Camacho	Cities of knowledge, municipalities and environment
Juliano A. de Oliveira, Leonardo T. Montero, Diogo R. da Costa, J. A. Méndez-Bermúdez, Rene O. Medrano-T, Edson D. Leonel	Structure of the parameter space for a family of two-dimensional mappings
Ixchel Garduño Alvarado	Frailty characterization with C. elegans in ageing and exposure to stressors
Rodolfo Gutierrez-Barron	Time series for a meteorological database of the Tambo Quemado station
Kevin Iglesias, G. Marcelo Ramírez-Ávila	Periodicity Characterized Synchronization in threesome of Rulkov neurons
A. Zambrano, M. F. Laguna, M. Kuperman, L. Nahuelhual, A. Monjeau, P. Laterra	Modelling the Fishers-Centolla System Dynamics
Guillermo Daniel Leonardini Gutiérrez, Mizky Bernal Miranda, Guillermina Miranda Torrez, G. Marcelo Ramírez-Avila	Complexity outcomes from the musical trios of W.A. Mozart and M. Feldman
Lucas Lozada, G. Marcelo Ramírez-Ávila	Experimental study of the rotating hoop with bead
Rok Cestnik, Sissi Lozada-Gobilard	eEvolution: a bottom up approach
Miriam Marilin Manrique Medina	Application of the Entropy of Approximation for the nonlinear characterization in patients with Chagas disease
Jorge Alejandro Mendoza Vargas, Henry Quispe Chuquitarqui, Luis Tito Huaylla	Determination of the correlation of movement between different sections of the protein structure analyzing the conformations by means of nuclear magnetic resonance.
Jorge Emiliano Navarro Morales, Alfredo Alejandro Alvarez Acuña	Deep Learning Image Recognition Algorithms used to classify dynamical behaviours
Sorge Alonzo Oporto Almaraz, G. Marcelo Ramírez-Ávila	Bifurcation fringe in the space of concentrations for the Belousov-Zhabotinsky reaction
Monica Garcia, Milena Paez, Francisco Pacheco	Design of a heterogeneous sustrate for Faraday waves formation in a water cell.
Flor Cardenas Cacya, Dayanne Pamo Coaquira, David Ychocan Ura	Correlation of movement between residues located in the disordered and ordinate areas, by means of classical molecular dynamics.
Miguel L. Peñafiel, F. T. Falciano, S. E. P. Bergliaffa	Bekenstein Bounds and Nonlinear Electrodynamics
Fernando Poma Ajoruro, Hugo Rivera	Study of high mountain neutron flux produced by cosmic rays through Monte Carlo simulations
Deterlino Urzagasti, Luzmila A. Quispe-Flores	Chaotic one-dimensional domains induced by periodic potentials in normal-dispersion fiber lasers
Gustavo M. Rodriguez B., Flavio Ghezzi	Study of fixed dipoles with fractal symmetry
M. G. Stojanović, M. Stojanović Krasić, M. Johansson, Ignacio Salinas, R.A. Vicencio, M. Stepić	Localized modes in two-dimensional octagonal-diamond lattices
Aurelio Alejandro Suxo Coro, G. Marcelo Ramírez-Ávila	Experimental obtention of galleries of attractors for Chua's and RL-Diode circuits and the study of synchronization in mutually coupled oscillators

Chapter Abstracts: Invited Speakers

The abstracts are organized alphabetically with respect to the last name of the author who presented it at LAWNP 2019. To consult for all the authors in alphabetical order, please refer to Author's Index section at the end of the document.

3.1 Flocking in open space: the role of long-range interactions

Maximino Aldana[1]

[1]*Instituto de Ciencias Físicas, UNAM, México*

Since the pioneering work by Vicsek and his collaborators on the motion of self-propelled particles, most of the subsequent studies have focused on the onset of ordered states through a phase transition driven by particle density and noise. Usually, the particles in these systems are placed within periodic boundary conditions and interact via short-range velocity alignment forces. However, when the periodic boundaries are eliminated, letting the particles move in open space, the system is not able to organize into a coherently moving group since even small amounts of noise cause the flock to break apart. While the phase transition has been thoroughly studied, the conditions to keep the flock cohesive in open space are still poorly understood. I this talk I will present an extension of the Vicsek model of collective motion by introducing long-range alignment interactions between the particles. The results show that just a small number of these interactions is enough for the system to build up long lasting ordered states of collective motion in open space and in the presence of noise. This finding was verified for other models in addition to the Vicsek one, suggesting its generality and revealing the importance that

long-range interactions can have for the cohesion of the flock.

3.2 Spatial Organization and Survival of Single Species Populations

Celia Anteneodo[1]

[1]*PUC-Rio, Brazil*

The spatial distribution of living organisms in heterogeneous environments is a central issue in the dynamics of biological populations. In particular, it is relevant to know how fragmented structures arise and, mainly, if in the long term the population will survive or become extinct. We address these problems for single species populations. The nonlinear Fisher-KPP equation provides a fundamental mathematical description of the spatial distribution at the mesoscopic level, governed by elementary processes (growth, competition for limited resources and random dispersion), and can be generalized in several realistic directions by including for instance: density-dependencies in growth and diffusion rates, selective mobility, fluctuations, all under appropriate boundary conditions. We will discuss the role of these factors, on the survival of the population, as well as on pattern formation and shaping.

3.3 Quantifying time-dependent media agenda and public opinion by topic modeling

Pablo Balenzuela[1], *Sebastián Pinto*[1] *and Federico Albanese*[2]

[1]*Departamento de Física, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Argentina*

[2]*Instituto de Investigación en Ciencias de la Computación (ICC), CONICET, Argentina*

The mass media plays a fundamental role in the formation of public opin-

ion, either by defining the topics of discussion or by making an emphasis on certain issues. Directly or indirectly, people get informed by consuming news from the media. Naturally, two questions appear: What are the dynamics of the agenda and how the people become interested in their different topics? These questions cannot be answered without proper quantitative measures of agenda dynamics and public attention. In this work we study the agenda of newspapers in comparison with public interests by performing topic detection over the news. We define Media Agenda as the distribution of topic's coverage by the newspapers and Public Agenda as the distribution of public interest in the same topic space. We measure agenda diversity as a function of time using the Shannon entropy and differences between agendas using the Jensen–Shannon distance. We found that the Public Agenda is less diverse than the Media Agenda, especially when there is a very attractive topic and the audience naturally focuses only on this one. Using the same methodology we detect coverage bias in newspapers. Finally, it was possible to identify a complex agenda-setting dynamics within a given topic where the least sold newspaper triggered a public debate via a positive feedback mechanism with social networks discussions which install the issue in the Media Agenda.

3.4 Quantum thermodynamics with repeated interaction and collisional models

Felipe Barra[1]

[1] *Universidad de Chile, Chile*

We consider the nonequilibrium statistical mechanics and thermodynamics of quantum systems. We start by considering open quantum systems evolving with a so-called boundary-driven Lindblad equation. We discuss in simple examples some of its properties and also consider them in the context of quantum thermodynamics [1]. We obtain a thermodynamically

consistent description of boundary-driven Lindblad models from the repeated interaction framework for the system and bath dynamics [2]. We discuss some interesting applications of these models [3] and explore differences and similarities of the thermodynamics and statistical mechanics for quantum systems in the repeated interaction framework and under collisional models [4].

References:

[1] F. Barra, Sci. Rep. 5, 14873 (2015).

[2] F. Barra and C. Lledó, Phys. Rev. E 96, 052114 (2017).

[3] F. Barra, Phys. Rev. Lett. 122, 210601, (2019).

[4] J. Ehrich, M. Esposito, F. Barra and J.M.R. Parrondo, Physica A https://doi.org/10.1016/j.physa.2019.122108 (In press, 2019).

3.5 The resonant structure of galaxy discs

John E. Beckman[1,2] *and Joan Font*[1,3]

[1]*Instituto de Astrofísica de Canarias, 38200, La Laguna, Tenerife , Spain*

[2]*Departamento de Astrofísica, Universidad de La Laguna, Tenerife, Spain*

[3]*Gran Telescopio Canarias, Spain*

The existence of spiral arms and bars as long lived features of galaxy discs can be accounted for by density wave theory. I will outline the theory and show how, even though it requires non-linear premises, a linear approximation gives remarkable agreement with observations. To show this I will present new and detailed observations of the key parameters of the density wave structure in discs, obtained using a novel technique. I will show evidence for multiple concentric density waves, with weak but clear coupling between them, and explain what this can tell us about disc evolution, and in particular about rotational braking by dark matter halos.

3.6 Weak chaos and finite time Lyapunov exponents

Marcus W. Beims[1]

[1]*Universidade Federal do Paraná, Brazil*

We investigate chaos in mixed-phase-space Hamiltonian systems using time series of the finite-time Lyapunov exponents. The methodology we propose uses the number of Lyapunov exponents close to zero to define regimes of ordered (stickiness), semiordered (or semichaotic), and strongly chaotic motion. The dynamics is then investigated looking at the consecutive time spent in each regime, the transition between different regimes, and the regions in the phase space associated to them. Applying our methodology to a chain of coupled standard maps we obtain (i) that it allows for an improved numerical characterization of stickiness in high-dimensional Hamiltonian systems, when compared to the previous analyses based on the distribution of recurrence times; (ii) that the transition probabilities between different regimes are determined by the phase-space volume associated to the corresponding regions; and (iii) the dependence of the Lyapunov exponents with the coupling strength. Intermittent stickiness synchronization is also discussed in this context.

3.7 Nonstationarities of physiological time series: detection and analysis

Sabrina Camargo[1], *Celia Anteneodo*[2], *Maik Riedl*[3], *Niels Wessel*[3] *and Jürgen Kurths*[1,3]

[1]*Universidade Federal do ABC, Brazil*

[2]*Pontifícia Universidade Católica do Rio de Janeiro, Brazil*

[3]*Humboldt Universität zu Berlin, Germany*

Physiological time series are typically non-stationary, demanding different approaches to be analyzed in terms of standard methods. Besides

environmental conditions, non-stationarities can arise from multiple regulatory mechanisms, for example blood flow and respiration, operating concomitantly and varying over time, with each subsystem presenting its own time scale. Several diseases and conditions, such as myocardial infarction, diabetic neuropathy, and myocardial dysfunction, are related to the reduction in heart rate variability. We present a non-parametric method which allows to identify changes in the physiological signal and split it into stationary patches, providing local quantities such as mean and variance of the signal in each stationary patch, as well as its duration. We explain the details of the segmentation method and how the outcomes of the segmentation can point to the complexity reduction in heart beating, due to pathological conditions and aging, and we discuss also the detection of sleep apnea through cardiovascular data. The outcomes of segmentation give us access to time characteristics of the signal that were no longer available, making possible a different approach to quantify non-stationarities in physiological time series.

3.8 Itinerary Synchronization Between Coexistence of Chaotic Attractors

Erick Campos-Cantón[1]

[1]*DMAp, Instituto Potosino de Investigación Científica y Tecnológica, México*

In this work, we present the generation of multiscroll chaotic attractors via heteroclinic orbits based on piecewise linear systems. The collective dynamics of a pair or more coupled systems with different number of scrolls is studied. There are different configuration to get a coupled system via unidirectional coupling or bidirectional coupling. In this work, the master-slave configuration is mainly studied. We investigate the synchrony behavior of different connected networks. Itinerary

synchronization is defined in terms of the symbolic dynamics arising by assigning different numbers to the regions where the scrolls are generated. A weaker variant of this notion, ϵ-itinerary synchronization is also explored and numerically investigated. Itinerary synchronization is used to detect synchrony behavior when the coupled system presents generalized multistability.

3.9 Learning to soar like a bird

Antonio Celani[1]

[1]*ICTP, Italy*

Soaring birds often rely on ascending air currents as they search for prey or migrate across large distances. The landscape of convective currents is rugged and rapidly changing. How soaring birds find and navigate thermals within this complex landscape is unknown. Reinforcement learning provides an appropriate framework to identify an effective navigational strategy as a sequence of decisions taken in response to environmental cues. I will discuss how to use it to train gliders to autonomously navigate atmospheric thermals, in silico and in the field.

3.10 Construction of Distinct Discrete Time Scattering Quantum Walk Formulations on the Honeycomb Lattice

Adam L. de Azevedo[1], *Fabio M. Zanetti*[1] *and Marcos G.E. da Luz*[1]

[1]*Universidade Federal do Paraná, Brazil*

Here we address the scattering construction of discrete time quantum walks on the honeycomb lattice. We write the system general (unitary) one step time evolution operator in terms of: (i) complete arbitrary scattering matrices S, defined on the sites (j,k) of the lattice and; and (ii) topological

directional functions Phi, which represent the distinct ways we can keep track of the propagation directions along the three bonds attached to each (j,k). By imposing the Phi's to comply with all the honeycomb translational and point group symmetries (in the case of S the same for all (j,k)), we obtain in total ten independent model versions, presenting different dynamical features. To study some of their traits, we consider the idea of 'characteristic paths' CPs (closely related to classical random walks), determining the CPs for each one of the ten formulations. We then discuss many numerical examples of time evolution dynamics for our scattering quantum walks. For the calculations we use few S's, as the Discrete Fourier Transform (DFT) and Grover matrices.

3.11 Quantum chaos and quantum measurement - Paradigms of information production on the smallest scales

Thomas Dittrich[1], *Carlos Viviescas*[1], *Frank Grossmann*[2] *and Walter Strunz*[2]

[1]*Departamento de Física, Universidad Nacional de Colombia, Bogotá D.C., Colombia*

[2]*Institute of Theoretical Physics, University of Technology Dresden, Germany*

Quantum chaos and quantum measurement have one constitutive feature in common: They capture information at the smallest scales and amplify it to macroscopic observability. Fundamental bounds on the information content of closed quantum system with finite-dimensional Hilbert space restrict their entropy production to a finite initial time span. Only in open systems where fresh entropy infiltrates from the environment, quantum dynamics (partially) recovers chaotic entropy production. In quantum measurements, a macroscopic apparatus observes a small quantum system. Typically, notably in spin measurement, their results involve

a component of randomness. The analogy with quantum chaos suggests that random outcomes of quantum measurements could, in a similar manner, reveal the entropy generated through the coupling to a macroscopic environment. It is required anyway to explain a crucial feature of quantum measurement, the decoherence that becomes manifest in the collapse of the wavepacket. However, the subsequent step from a set of probabilities to specific individual measurement outcomes (the "second collapse") still evades a proper understanding in microscopic terms and remains shrouded in concepts such as "quantum randomness". Could this process be explained by the back action of the macroscopic apparatus on the measured system? While obviously, information on the measured system must reach the apparatus, this would mean that also conversely, information originating in the apparatus would be shared with the object. To explore this hypothesis in the case of spin measurements, we adopt the microscopic model of the measurement process proposed by Zurek and others and combine it with a unitary approach to decoherence, used in quantum chemistry and quantum optics, with heat baths comprising only a finite number N of modes. We expect the dynamics of the measured spin for growing N to exhibit a transition to a scenario of increasingly abrupt collapses and revivals: episodes of significant spin polarization of increasing length alternating with spin flips, determined by the initial condition of the apparatus. Preliminary analytical and numerical results confirm our expectation. Complementing the quantum model, we study an analogous classical system: A particle, launched from the top of the barrier of a symmetric double-well potential, will fall into either well, depending on random impacts by ambient degrees of freedom to which it couples.

3.12 Self-organization in one-dimensional systems of interacting Brownian particles: synchronous vs asynchronous updates

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We study a one-dimensional system of off-lattice Brownian particles that interact among themselves through a local velocity-alignment force that does not affect their speed. These conditions restrict the implementation of the aligning forces to a time-based scheme that allows for two different cases to be analyzed: synchronous and asynchronous updates. In the first, velocity-alignment is implemented periodically throughout the whole system while, in the second, probabilistically at every time-step in a Monte Carlo fashion. As the frequency of alignment increases in the synchronous case, or the probability of alignment in the asynchronous one, the system is driven from stationary states close to thermal equilibrium to far-from-equilibrium ones, where the system exhibits spontaneous symmetry breaking and self-organization characterized by long-range order and giant number fluctuations, features typically observed in ordered states of interacting self-propelled particles. Our results show that self-propulsion is not necessary to induce the flocking transition even in one-dimensional systems. Moreover, in the synchronous version of our model, the order parameter shows a regular spiking and resetting activity in the ordered phase, with fluctuations fading with the density, nonetheless, the system is still susceptible to turbulence and transient global disorder typical of these kind of out-of-equilibrium phases. On the other hand, some anomalous statistics for the higher moments of the order parameter become apparent

in the disordered phase. Finally, we also analyze the case where self-propulsion is gradually included in the dynamics. In this case, the critical point decreases as self-propulsion becomes stronger in comparison with the cases without it.

3.13 Nested sequences of arithmetic progressions in a discrete neuron model

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Rulkov's discrete-time neuron model is known to display stability phases characterized by trains of pulsing and bursting signals having a multitude of spikes scattered in the control parameter space. By performing a systematic classification of such complex oscillations, we discovered nested sequences of arithmetic progressions among adjacent phases of pulsing and bursting. Such nested progressions can be expressed in terms of simple linear combinations of two "basic" periods. Nestings are robust and can be observed abundantly in distinct control parameter planes that are described in detail.

3.14 Rabi-like oscillations in a dissipative system

Mónica A. García-Ñustes[1], *Fernando Mellado-Humire*[1] *and Yogesh Joglekar*[1]

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In this work, we show recent results on pattern formation in a parametric system subject to a heterogeneous forcing. We explore the presence of Rabi-like oscillations in a dissipative (out-of-equilibrium) system. We also present some experimental realizations conducted in a shallow water trough subjected to a parametric force with a tunable localization. New perspectives and future works will be discussed.

3.15 Temporal fluctuations in musical performances

Theo Geisel[1] [1]*MPI Göttingen, Germany*

It is commonplace that human musical performances differ in various aspects from the corresponding musical scores or their transcription into MIDI-sequences. An important such aspect are so-called microtiming deviations, slight temporal deviations from the exact rhythm, that were claimed e.g. to play a key role for the swing feeling in jazz music. This claim, however, is so far discussed controversially in the musicological literature. In previous work using time series analysis we were able to identify differences between microtiming deviations of rock and jazz music. Here we report the results of an online survey among groups of musicians to whom we presented different versions of jazz music with original and manipulated microtiming deviations in an attempt to better characterize the phenomenon of swing.

3.16 Coherent state based approaches to quantum dynamics

Frank Grossmann[1]

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Already in 1926, Schroedinger had pointed out the importance of Gaussian wavepackets in the transition from micro- to macro-mechanics [1]. We discuss the connections of different approximate and numerically exact ways, based on Gaussian wavepackets, to solve the time-dependent Schroedinger equation for a many-particle system. Special emphasis will be laid upon trajectory-guided coherent states that are, e.g., used in semiclassical initial value representations of the propagator [2]. Furthermore, some recent progress in numerical implementations of the Davydov-Ansatz for spin-boson models will be presented [3]. The possibility to combine the recent progress in the two so far disconnected approaches will be elaborated on.

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3.17 Abrupt epidemic spreading

Hans Herrmann[1]

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Advances in mathematical epidemiology have led to a better understanding of the risks posed by epidemic spreading and strategies to contain disease spread. However, a challenge that has been overlooked is that, as a disease becomes more prevalent, it can limit the availability of the resources needed to effectively treat those who have fallen ill. Here a simple generalized Susceptible-Infected-Susceptible (SIS) model is used to gain insight into the dynamics of an epidemic when the recovery of sick individuals depends on the availability of healing resources that are generated by the healthy population. The epidemics can spiral out of control into explosive spread, if the cost of recovery is above a critical cost. This can

occur even when the disease would die out without the resource constraint. The onset of explosive epidemics is very sudden, exhibiting a discontinuous transition under very general assumptions. Analytical expressions can be given for the critical cost and the size of the explosive jump in infection levels in terms the parameters that characterize the spreading process. The model and its results apply beyond epidemics to contagion dynamics that self-induce constraints on recovery, thereby amplifying the spreading process. The spread of an infection is also investigated when a system component can recover only if it remains reachable from a functioning central unit. More precisely, infection spreads from infected to healthy nodes, with the constraint that infected nodes only recover, if they remain connected to a pre-defined central node, through a path that contains only healthy nodes. In this case, clusters of infected nodes will absorb their non-infected interior, because then no path exists between the central node and encapsulated nodes. This gives rise to the simultaneous infection of multiple nodes. Interestingly, the system converges to only one of two stationary states: either the whole population is healthy or it becomes completely infected. This simultaneous cluster infection can give rise to discontinuous jumps of different sizes in the number of failed nodes. Larger jumps emerge at lower infection rates. The network topology has an important effect on the nature of the transition: hysteresis appears for networks with dominating local interactions. The model shows how local spread can abruptly turn uncontrollable, when it disrupts connectivity at a larger spatial scale. We introduce a general mathematical framework to describe and classify a variety of spreading dynamics. Interestingly, some scenarios turn out to exhibit spontaneous, unpredictable breakdown and recovery cascades. To foster the recovery of damaged or infected systems, we also propose a targeted recovery protocol where least- damaged or infected regions recover first. This can lead to spatial confinement of

the infection within a well- defined radius.

3.18 Secure transmission of information trough coexisting chaotic attractors

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A secure communication scheme is described based on a chaotic multistable system. Both the emitter and the receiver of the communication system are conformed by two Rösslle oscillators with nonlinear coupling. Varying the initial condition of one of the system variable results in different periodic or chaotic regimes. Synchronization between emitter and receiver is reached by a private communication channel, while the information transmission is realized by a public channel adhering a message package in a staggered manner to coexisting chaotic states within the same time series. The changing sequence of the initial condition acts as a dynamical private secrete key, while the parameters of the Rösslle oscillators are considered as a static public key. The high security of the proposed communication system is provided by a change in the system parameters faster than synchronization time, so that synchronization attacks are ineffective.

3.19 Bulbous plants precisely measure the lenght of winter and adjust flowering dates

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In order to identify the most relevant environmental parameters that regulate flowering time of bulbous perennial plants, first flowering dates of 329 taxa over 33 years are correlated with monthly and daily mean values of 16 environmental parameters spanning at least one year back from flowering. A machine learning algorithm is deployed to identify the best fitting parameters because the problem is strongly overdetermined for traditional methods. Surprisingly, the best proxy of flowering date fluctuations is the daily snow depth anomaly even for species flowering in October. Moreover, this proxy performs much better than mean soil temperature preceding the flowering, the best monthly explanatory parameter. Our findings support the existence of complicated temperature sensing mechanisms operating on different time scales, which is a prerequisite to precisely observe the length and severity of the winter season and translate e.g., "lack of snow" information to meaningful internal signals related to phenophases.

3.20 From dissipation-induced instability to the dynamics of engines

Alejandro Jenkins[1]

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In the 1930s, Philippe Le Corbeiller proposed connecting the mathematical theory of Lyapunov stability with the thermodynamics of engines (understood as devices capable of generating and maintaining a cyclic

motion at the expense of an external disequilibrium without any corresponding periodicity). Unfortunately, this had little impact in the scientific community and was not developed very far by Le Corbeiller himself. I will argue that Le Corbeiller's program is still a promising way forward in the theory of non-equilibrium thermodynamics, which until now has, for the most part, failed to capture the detailed dynamics of work extraction by engines. In classical physics, such work extraction requires an active, non-conservative force, something that has been studied almost exclusively in the context of mechanical instabilities. I will treat three separate problems: the generation of waves on the surface of the water by the action of the wind, the hunting oscillation of a train, and the tidal acceleration of the Moon. I will show how the dialogue between dynamical systems theory and thermodynamics simplifies the solutions to these problems while revealing surprising commonalities among them. Finally, I will also argue that a similar approach can throw light on the thermodynamics of non-conservative chaotic systems, including Chua's circuit and the Lorenzian waterwheel.

3.21 Traveling amplitude death in coupled pendula

Tomasz Kapitaniak[1]

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We investigate the phenomenon of amplitude death [in two scenarios—traveling (TAD) and stationary] in coupled pendula with escapement mechanisms. The possible dynamics of the network is examined in coupling parameters' plane, and the corresponding examples of attractors are discussed. We analyze the properties of the observed patterns, studying the period of one full cycle of TAD under the influence of system's parameters, as well as the mechanism of its existence. It is shown, using the energy

balance method, that the strict energy transfer between the pendula determines the direction in which the amplitude death travels from one unit to another. The occurrence of TAD is investigated as a result of a simple perturbation procedure, which shows that the transient dynamics on the road from complete synchronization to amplitude death is not straightforward. The pendula behavior during the transient processes is studied, and the influence of parameters and perturbation magnitude on the possible network's response is described. Finally, we analyze the energy transfer during the transient motion, indicating the potential triggers leading to the desired state. The obtained results suggest that the occurrence of traveling amplitude death is related to the chaotic dynamics and the phenomenon appears as a result of completely random process.

3.22 Models and experiments on pedestrian evacuation

Marcelo Kuperman[1]

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The study of pedestrian dynamics has been receiving great attention during the last years. The interest on the subject traverses the several areas of knowledge and researchers from a broad spectra of disciplines are studying those phenomena from complementary points of view. Of particular interest is the dynamics of an evacuation process. During an evacuation, pedestrians need to abandoned an enclosing through one or more available exits, some times narrow enough to generate tragic events. The complex nature of this process allows to trace links with studies in granular matter and game theory among others. In this talk we will focus in the interplay of these two areas to formulate mathematical models and to study and understand experimental data. The novelty introduced in our approach is to consider behavioural aspects related to the decision taking of the

pedestrians at the moment of approaching the exit and interacting with other pedestrians. We will show how three different methodologies that include the mentioned behavioural aspects in the description of an evacuation process lead to the same phenomenology, not fully explained by previous works.

3.23 Mathematical models of extinction and coexistence in complex ecological networks

María Fabiana Laguna[1]

[1]*Statistical and Interdisciplinary Physics Group, Centro Atómico Bariloche and CONICET. Bariloche, Argentina*

The use of mathematical models in Ecology has grown significantly in the last decade. This is due in part to their predictive capacity, but also to their power to order and systematize assumptions and thus contribute to elucidate the behavior of complex biological systems. In fact, the interrelation of factors as diverse as climate, access to resources, predators and human activity, makes it necessary to develop mathematical models that allow predicting the effect of each of them on the species involved, showing possible scenarios of coexistence or extinction in spatially structured populations. A large number of publications on topics such as predator-prey models, intra- and inter-specific competition, or habitat fragmentation can be found, but more research is still needed on how to integrate 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 predator-prey-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 fluctuations and spatial correlations. I will present some recent results obtained with more realistic versions of the models we initially explored. 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.

3.24 Bifurcation in random dynamical systems

Jeroen S.W. Lamb[1]

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While topical applications increasingly rely on models of dynamical systems driven by noise, the corresponding theory for random dynamical systems still remains in its infancy. This talk surveys some recent insights into how random dynamical systems may exhibit bifurcations, i.e. qualitative changes in dynamical behaviour under the variation of parameters.

3.25 Chaotic diffusion for a family of area preserving mappings

Edson Denis Leonel[1]

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The chaotic diffusion for a family of Hamiltonian mappings whose angles diverge in the limit of vanishingly action is investigated by using the solution of the diffusion equation. The system is described by a two-dimensional mapping for the variables action,I, and angle, θ and controlled by two control parameters: (i)ϵ, controlling the nonlinearity of the system, particularly a transition from integrable for $\epsilon = 0$ to non-integrable for $\epsilon \neq 0$ and; (ii)γ denoting the power of the action in the

equation defining the angle. For $\epsilon \neq 0$ the phase space is mixed and chaos is present in the system leading to a finite diffusion in the action characterized by the solution of the diffusion equation. The analytical solution is then compared to the numerical simulations showing a remarkable agreement between the two procedures. For the chaotic dynamics far apart from the periodic islands, normal diffusion is observed. The scenario changes significantly when the dynamics passes near stability regions where anomalous diffusion dominates over the dynamics, stickiness is present and a temporary break of ergodicity is observed.

3.26 Aerodynamics and percolation

Pedro G. Lind,[1]

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We argue that the applicability of percolation models can be extended from fundamental fluid dynamics to practical aerodynamics relevant for engineering problems and, thus, to a more generally valid concept. As a fundamental phenomenon of fluid mechanics, recent studies suggested laminar-turbulent transition belonging to the universality class of directed percolation. Here, the onset of a laminar separation bubble on an airfoil is analyzed in terms of the directed percolation model using particle image velocimetry data. Our findings indicate a clear significance of percolation models in a general flow situation beyond fundamental ones. We show that our results are robust against fluctuations of the parameter, namely, the threshold of turbulence intensity, that maps velocimetry data into binary cells (turbulent or laminar). In particular, this percolation approach enables the precise determination of the transition point of the laminar separation bubble, an important problem in aerodynamics. Finally, we also put our findings into perspective, discussing possible applications

of our framework to rotor blades of wind turbines and in computer fluid dynamics approaches to turbulence.

3.27 Characterizing the exceptional 2014 drought event in Sao Paulo by drought period length

Elbert E. N. Macau[1], *Yong Zou*[2], *Gilvan Sampaio*[3] *and Jürgen Kurths*[4]

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[2]*East China Normal University, Shangai, China*

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In the last decade, the southeast region of Brazil has been suffering severe water shortages. Here, we propose to compute the expected drought period length to characterize the drought events in the region of São Paulo. We report the unique properties of the exceptional drought event during the austral summer 2014 by showing the differences and similarities to the very dry season in 2001 and the mild dry seasons in 2006 and 2015. Furthermore, we investigate the correlations of the abnormal precipitation deficit with the ocean and atmospheric patterns.

3.28 Mathematical Billiards. Results and methods

Roberto Markarian[1]

[1]*IMERL, Facultad de Ingeniería, Universidad de la República,Uruguay*

We will present a survey of results and methods on the mathematical theory of billiards. We will focus on ergodic and statistical properties of classical billiard systems in the plane. The invariant measure for these systems was studied by Birkhoff in the twenties and the ergodic theory was developed by the soviet school in the sixties - seventies, specially in the

seminal works of Jacob Sinai. Relations with the ergodic hypothesis of Boltzmann and properties of the geodesic flow were well understood from the very beginning. The survey will include references to my own work on ergodic and statistical properties, and recent results related with decay of correlations and Poisson processes using new methods by, among others, Lai-Sang Young, Carlangelo Liverani, Mark Demers, Dmitry Dolgopyat, Viviane Baladi, Pierre Collet, Hong-Kun Zhang, Ian Melbourne, Pierre Collet, Francoise Pène.

3.29 Data-driven methods for anticipating dynamical transitions and inferring the connectivity of oscillatory systems

Cristina Masoller[1]

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In complex systems research, detecting correlations that capture genuine interactions, and anticipating dynamical transitions directly from the observed signals, are challenging tasks with applications across disciplines. In the first part of this talk I will consider networks of oscillators and I will discuss how the analysis of the mutual lags between pairs of oscillators can yield useful information for inferring the system connectivity, and also, for anticipating the transition to synchrony. Synthetic datasets from Kuramoto oscillators and empirical datasets from Rossler-like chaotic electronic circuits will be analyzed. In the second part of the talk I will consider a global empirical climatological dataset (surface air temperature) and I will discuss how the analysis of the instantaneous amplitudes and phases of the seasonal cycles in different geographical regions, computed by using the Hilbert transform, allows to disentangle climatic processes and to track atmospheric waves that propagate across the planet.

3.30 The role of chaotic transient in synchronization of networked systems

Everton S. Medeiros[1], *René O. Medrano*[2], *Iberê L. Caldas*[1], *Tamás Tél*[3] *and Ulrike Feudel*[4]

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Consider a synchronized network where each unit presents only a periodic attractor with a chaotic transient. Depending on the instant that a perturbation is applied, we observe two possible network long-term states: (i) The network neutralizes the perturbation effects and returns to its synchronized configuration. (ii) The perturbation leads the network to an alternative desynchronized state. We show that this time-dependent vulnerability of synchronized state is due to the existence of a fractal set of initial conditions conducing the dynamic to a chaotic set in which trajectories persist for times indefinitely long. We argue that this phenomenon is general and illustrate with a complex network composed of electronic circuits.

3.31 Molecular interactions in cellular processes, a perspective from simulations

Viviana Monje-Galvan[1] *and Gregory A. Voth*[1]

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Molecular dynamics (MD) studies can be critical to study specific protein-lipid interactions in a given system. Based on statistical thermodynamics, these simulations predict the trajectory of a system based on the forces

that act on each of the components. The trajectory is obtained by solving Newton's law of motion for every component in the system at a given time step. The simulation parameters are called a 'force field' and are determined based on experimental and quantum mechanics for bonded, non-bonded, and short/long rage electrostatic interactions. Using MD, we are interested in understanding the effect of protein binding and aggregation on membrane dynamics in retroviral assembly. Specifically, our studies advance the understanding of key mechanisms in the viral assembly process of HIV-1 and offer potential new perspectives for antiretroviral treatments. Additionally, this work shows the importance of accurate membrane models to study protein dynamics through simulation, and provides insights into relevant interactions between lipidated peripheral proteins on the membrane surface. We built both symmetric and asymmetric membrane models and simulated a single as well as multiple protein units of the membrane targeting domain of Gag, a key protein for HIV assembly at the plasma membrane during. We explored the role of lipid co-localization to the protein binding site and its relationship to the insertion of the lipidated tail of this motif. These observations contribute to our understanding of molecular interactions that prepare a region in the plasma membrane for viral assembly and budding.

3.32 Spontaneous rotation in vibrated packings

Cristian F. Moukarzel[1], *Gonzalo G. Peraza-Mues*[1] *and Osvaldo Carvente*[2]

[1]*CINVESTAV, México*

[2]*UADY, México*

We show that polydisperse packings of frictional elastic disks under gravity self-organize, when vibrated vertically with moderate intensities,

onto a rotational state where the average angular velocity $mrvel_i$ of each disk i is nonzero when measured over times much longer than the collision time. This previously unobserved phenomenon is studied here by means of experiment and numerical simulation, finding an excellent degree of phenomenological agreement between both methods.

3.33 Cellular automata for car traffic and lattice Boltzmann models for curved coordinates: the taste of discreteness

José Daniel Muñoz[1]

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Cellular automata are powerful tools to simulate car traffic. By dividing the streets into cells where individual cars move at discrete time steps, they can simulate streets, neighborhoods, massive transportation systems and even whole cities. They can investigate the effect of an individual behaviour on the system's performance, and some of their models exhibit anisotropic phase transitions. In contrast, lattice Boltzmann are more adequate to model continuous systems with a set of conservation laws. A hypothetical fluid carries the information from cell to cell and collides by following the Boltzmann's transport equation, a procedure that is fully parallel and can be easily implemented on graphic cards. Although the method has been successful to simulate fluids, acoustics, diffusion, electrodynamics and even general relativity and non-linear media, its use has been limited by the fact that most of them works on uniform Cartesian grids only. Hereby we show recent results on car traffic cellular automata and on the design of lattice Boltzmann models for generalised curvilinear coordinates that illustrate the power of such discrete models.

3.34 Rare events in coupled lasers

Carlos L. Pando L.[1] *and Eusebius J. Doedel*[2]

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[2]*Concordia University, Montreal, Canada*

We present a study for a laser system consisting of two coupled laser oscillators, each of which shows mixed-mode oscillations and chaos when uncoupled. The type of coupling is via saturable absorbers, which is akin to inhibitory nonlinear coupling in neurons. We have carried out numerical bifurcation analysis and numerical simulations to show that for small enough coupling, well below the synchronization threshold, the onset of certain resonances in a symmetric configuration induce a type of rare events characterized by a very small amplitude. For an asymmetric configuration, we observe extreme rare events (rogue waves), which occur near an in-phase Hopf bifurcation. In both configurations, the rate of these rare events can be tuned by suitably changing physically relevant parameters. We observe similar rare events in other settings composed of these laser oscillators.

3.35 Packing of circular filamentous matter

Leopoldo R. Gómez[1], *Nicolás A. García*[2], *Jean-Louis Barrat*[2,3] *and Thorsten Poeschel*[4]

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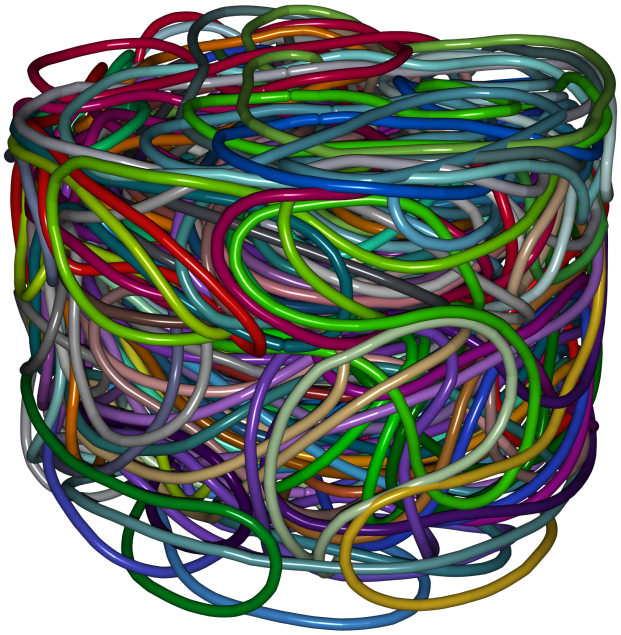
Unravelling the packing structure of dense assemblies of semiflexible rings is not only fundamental for the dynamical description of polymers



rings, but also key to understand biopackaging, such as observed in circular DNA inside viruses or genome folding. Here we use X-ray tomography to study the geometrical and topological features of disordered packings of rubber bands in a cylindrical container. Assemblies of short bands are found to display a liquid-like disordered structure, with short-range orientational order and a minor influence of the container. On the contrary, as the bands become longer, confinement force folded configurations and the bands interpenetrate and entangle. The degree of entanglement is characterized through minimal surfaces and generalized Voronoï diagrams, which allow the identification of bands threadings and near neighbors. Most of the systems are found to display a threading network which percolates the system. Interestingly, for long bands whose diameter doubles the diameter of the container, we found that all bands interpenetrate each other, in a complex fully-entangled structure.

3.36 Chaos and phase transitions of a probabilistic cellular automata

Franco Bagnoli[1] *and Raúl Rechtman*[2]

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A one dimensional probabilistic cellular automaton with two absorbing states is discussed. Given a quenched random field, the time evolution is deterministic and chaos can be defined. The time evolution depends on two continuous parameters and it makes sense to study phase transitions as a function of these parameters. Synchronization and control are also discussed.

3.37 Chimera states in a Duffing oscillators chain

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We show the coexistence of coherent and incoherent states, chimera states, in a simple Duffing oscillators chain coupled to nearest neighbors. These intriguing states are observed in the bistability region between a uniform oscillation and a spatiotemporal chaotic state. To characterize the chimera states rigorously, we compute their Lyapunov spectra. Depending on initial conditions, a family of chimera states can appear and disappear, following a snaking-like bifurcation diagram.

3.38 Binary black hole shadows: chaos in general relativity

Miguel A. F. Sanjuán[1]

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General relativity – itself a nonlinear field theory – naturally leads to deterministic chaos. For example, the fate of a photon approaching a pair of black holes can be essentially indeterminate, even though it is governed by a deterministic set of equations. Here we explore the intricate structure of the shadow cast by the event horizons of a pair of black holes (BHs). An exciting era for gravitational astronomy is underway. In 2015, the first direct observation of gravitational waves (GWs), by the LIGO/Virgo collaboration, confirmed that binary black holes exist in Nature. The Event Horizon Telescope (EHT) has begun observing nearby galactic centres, and on April 10, 2019, the first picture of a BH shadow at the center of the M87 galaxy was shown. A BH shadow is associated with the set of all photons which, when traced backwards in time from the observer, asymptote towards the event horizon of the BH. In the language of nonlinear dynamics, a BH shadow is an exit basin in an open Hamiltonian dynamical system. Motivated by the GW detections from merging binary BHs, and the future prospects of the EHT, much work has focused on what the shadow of a pair of BHs would look like. The null geodesic equations, which describe the propagation of photons, are non-integrable, and chaotic scattering of photons emerges naturally. One of the hallmarks of chaos is the presence of fractal structures in phase space. In a binary BH system, a photon meets one of three possible fates: it falls into the first BH, the second BH, or it escapes to infinity. Thus, it is natural to define three exit basins. And across the phase space the shadow may exhibit both a regular and a fractal structure. Furthermore, in certain

parts of the phase space, the three basins have the more restrictive property of Wada. For the binary BH system, this means that a photon which starts close to a Wada boundary in phase space is uncertain and could end up in one of three final states: the photon could fall into either of the black holes, or escape to spatial infinity. We apply a recently-developed numerical method, the merging method [1] to test for the Wada property in the fractal structures that arise in a binary BH model in general relativity. To our knowledge, this work [2] represents the first demonstration of the Wada property for a general-relativistic system. As well as demonstrating that tools from the field of chaos theory can be used to understand the rich dynamics of scattering processes in general relativity, this work highlights that there exist novel dynamical systems in gravitational physics which can be fruitfully explored by nonlinear dynamicists.

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3.39 Exploring chaos and fractals in binary black holes

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3.40 Bacteria driving droplets

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From intracellular protein trafficking to large scale motion of animal groups, the physical concepts driving the self-organization of living systems are still largely unraveled. Self-organization of active entities, leading to novel phases and emergent macroscopic properties, recently shed new lights on these complex dynamical processes. Here we show that, under the application of a constant magnetic field, motile magnetotactic bacteria confined in water-in-oil droplets self-assemble into a rotary motor exerting a torque on the external oil phase. A collective motion in the form of a large-scale vortex, reversable by inverting the field direction, builds-up in the droplet with a vorticity perpendicular to the magnetic field. We study this collective organization at different concentrations, magnetic fields and droplets radii and reveal the formation of two torque-generating areas close to the droplet interface. We characterize quantitatively the mechanical energy extractable from this new biological and self-assembled motor. In a second set of experiment, we confine non-magnetic bacteria (*E. coli*) inside water-in-oil droplets. Here, the bacterial suspension does not develop a global vortex but, rather, the collective dynamics takes the form of small short-lived vertices in a turbulent-like motion. This collective motion of the suspension is able to move the droplet, which performs a persistent random walk. The measured persistence time and diffusion coefficient are of the order of 0.3 s and 0.5 mu m^2/s, respectively, several orders of magnitude larger than for a passive droplet. PIV measurements of the velocity field inside the droplet show that the droplet moves antiparallel to the bacteria, consistent with a rolling and slipping motion. The two examples demonstrate that bacteria can be used to build motors made of motors, that is, microscopic organisms can transfer useful mechanical energy to their confining environment, opening the way to the assembly of mesoscopic motors.

3.41 Semiclassical methods in Fock space

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The issues around the quantization of classically chaotic systems that, under the name of quantum chaos provided a deep insight into the nature of the quantum-classical transition, have now reached the stage of maturity and sophistication where they necessarily collide with some of the deepest problems in the whole Physics. Three of such open questions concern, i) the ultimate relation between the classical and quantum world and the role of nonlinear and dissipative dynamics, ii) the large amount of evidence pointing to chaos in the quantum mechanical description of black holes, and iii) the description of the classical limit of lattice field theories with finite dimensional local Hilbert spaces typical of quantum information theory. In this talk, I will present some of the efforts of the semiclassics community to contribute to this problems by means of extending the incredible success of quantum chaos in particle systems into the realm of quantum fields.

3.42 Electrocatalytic oscillations on model surfaces

Hamilton Varela[1]

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Reaction rates and the mechanism of most electrocatalytic reactions are known to critically depend on the structure of the electrode surface. Examples of structure sensitive electrocatalytic reactions are abundant and include the electro-oxidation of carbon monoxide, formic acid, methanol, etc., on platinum. Even more intricate is the effect of the interfacial structure on the oscillatory dynamics usually observed in those systems.

This is somewhat expected because several adsorption and reaction steps are simultaneously active during self-organized potential or current oscillations. Herein we present results of the effect of surface structure on the oscillatory electro-oxidation of methanol and glucose on platinum. The oxidation of methanol was investigated in acidic media on Pt(111), Pt(110), and Pt(100), and stepped surfaces Pt(776), Pt(554), Pt(775), and Pt(332); for glucose, oscillations were studied in alkaline electrolyte on polycrystalline platinum (Ptpoly), Pt(111), Pt(110), and Pt(100). For methanol, very tiny differences in the amount of surface defects were identified by means of the oscillatory pattern. For the electro-oxidation of methanol on stepped surfaces, we observed specificities in the dynamics that were unambiguously assigned to the surface structure. The following features were found according to the specific surface used: period-adding sequences of mixed-mode oscillations; a new type of mixed-mode oscillation; and a particular separation between two types of sequential oscillations. The electro-oxidation of glucose in alkaline media was found to strongly depend on the surface structure, with dramatic differences in the reaction currents, shape of the cyclic voltammogram and also in the onset potential. The potential oscillations were astonishingly stable and of high amplitude on Ptpoly. Pt(111) seems to be the less susceptible to poisoning and no oscillations were found on it. On Pt(110), large amplitude oscillations similarly to that on Ptpoly prevail. The presence of (100) sites brings about a secondary instability and new oscillations emerge. Temporal patterns on Pt(100) set in through small amplitude oscillations which further develop into very rich mixed-mode ones. In this case, higher frequency cycles observed around intermediate potentials and very well defined period-adding sequences appear. Overall, the observed results also indicate that electrochemical oscillations are much more sensitive to the surface structure than conventional electrochemical signatures, c.f.

voltammetry, and thus can be used to infer on the evolution of the catalyst as the reaction proceeds. To understand the relationship between the surface structure and the underlying dynamics of the surface chemistry during oscillations is a key challenge and results in this direction will be also discussed.

3.43 Detection of dysautonomy and enervation in patients with chagas diseage using hrv and entropy

Miguel Vizcardo[1] *and Juán R. Díaz*[1]

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Chagas disease American trypanosomiasis is caused by a flagellated parasite: *Trypanosoma cruzi*, transmitted by an insect of the genus *Triatoma* and also by blood transfusions. In Latin America, the number of infected people is approximately 6 million, with a population exposed to the risk of infection of 550 000. It is our interest to develop a non-invasive, low-cost methodology, capable of detecting any early cardiac alteration by *T. cruzi*. We analyzed 24-hour RR records in patients with abnormal ECG (CH2), patients without ECG abnormalities (CH1) who had positive serological findings for Chagas disease and healthy (Control) matched by sex and age. We found significant differences between Control and CH2 that show the dysautonomy and enervation of the autonomic nervous system.

3.44 Grazing induced bifurcations: innocent or sinister?

Marian Wiercigroch[1]

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In this lecture I will examine nature of subtle phenomenon such grazing bifurcations occurring in non-smooth systems. I will start with linear oscillators undergoing impacts with secondary elastic supports, which have

been studied experimentally and analytically for near-grazing conditions [1]. We discovered a narrow band of chaos close to the grazing condition and this phenomenon was observed experimentally for a range of system parameters. Through stability analysis, we argue that this abrupt onset to chaos is caused by a dangerous bifurcation in which two unstable period-3 orbits, created at "invisible" grazing collide [2]. The experimentally observed bifurcations are explained theoretically using mapping solutions between locally smooth subspaces. Smooth as well as non-smooth bifurcations are observed, and the resulting bifurcations are often as an interplay between them. In order to understand the observed bifurcation scenarios, a global analysis has been undertaken to investigate the influence of stable and unstable orbits which are born in distant bifurcations but become important at the near-grazing conditions [3]. A good degree of correspondence between the experiment and theory fully justifies the adopted modelling approach. Similar phenomena were observed for a rotor system with bearing clearances, which was analysed numerically [4] and experimentally [5]. To gain further insight into the system dynamics we have used a path following method to unveil complex bifurcation structures often featuring dangerous co-existing attractors.

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Chapter Abstracts: Oral Presentation

The abstracts are organized alphabetically with respect to the last name of the author who presented it at LAWNP 2019. To consult for all the authors in alphabetical order, please refer to Author's Index section at the end of the document.

4.1 Propagation of wet oxidation front in aluminum-rich layers: theory and experiments

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We propose a reaction-diffusion equation to model the bidimensional propagation of a wet oxidation front in thin aluminum-rich layers. The model includes adequately the anisotropies of the system. It can be used with any starting geometry, and it can be applied to other oxides. Our numerical simulations for simple and complex starting geometries are in excellent agreement with experimental observations.

4.2 Vlasov dynamic solutions of a mean field model with long range interactions

Boris Atenas[1] *and Sergio Curilef*[1]

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The present work is devoted to describing the Quasi-Stationary-States (QSS) involved in the d-HMF model (dipole Hamiltonian Mean Field Model) introduced by Atenas and Curilef 2017 [1], which was inspired in the dipole-dipole interactions, neglecting the distance dependence. The model is a variation of the Ising model, but it involves long-range interactions. Its Hamiltonian is similiar to the HMF model, which is a toy model widely used by several authos for study the the dynamics and thermodynamics in systems with long range interactions. Both models share several properties, except the symmetry, which makes the d-HMF model interesting. In the study of the stationary solutions, we found analytical solutions of the Vlasov equation, which are highly non-linear. We have obtained the analytical solution for the equilibrium by Boltzmann-Gibbs distribution and for the QSS out of the equilibrium by means of a Vlasov distribution type Tsallis. The results are relevant because they are found by means of optimization and variational methods, which are different ways to commonly used in the literature, where several authors try to find distributions using a fitting parameter q contrasting with simulations or experimental data. Additionally, we attempt to formally connect to thermodynamics and Tsallis statistics.

References:

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4.3 Characterization of the synchronization of 3 mobile oscillators using as a coupling model that of the three-body problem

Roy O. E. Bustos-Espinoza[1] *and G. Marcelo Ramírez-Ávila*[1]

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he synchronization of 3 coupled mobile oscillators is characterized by applying some of the techniques used for 2 [1]. The use of the logistic map is proposed as a fundamental dynamic for each oscillator and an interaction model, initially fixed and then another distance dependent, based on the restricted three body problem, i.e. two oscillators strongly coupled and the other one with a weak coupling with each others. It is intended to study the periodicities of the synchronization factor [2] as an analysis tool. We will seek to apply the results found.

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4.4 Inferring the dynamics of oscillatory systems using recurrent neural networks

Rok Cestnik[1], *and Markus Abel*[1]

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We investigate the predictive power of recurrent neural networks for oscillatory systems not only on the attractor but in its vicinity as well. For

this, we consider systems perturbed by an external force. This allows us to not merely predict the time evolution of the system but also study its dynamical properties, such as bifurcations, dynamical response curves, characteristic exponents, etc. It is shown that they can be effectively estimated even in some regions of the state space where no input data were given. We consider several different oscillatory examples, including self-sustained, excitatory, time-delay, and chaotic systems. Furthermore, with a statistical analysis, we assess the amount of training data required for effective inference for two common recurrent neural network cells, the long short-term memory and the gated recurrent unit.

4.5 Route to oscillation death in mutually coupled light-controlled oscillators

Gabriela Conde-Saavedra[1], *and G. Marcelo Ramírez-Ávila* [1]

[1] *University of Potsdam, Germany*

While the characterization of the synchronous behavior of a system of two mutually coupled light-controlled oscillators (LCOs) has been extensively studied, few studies were done when coupling strength takes high values and none for the case in which a strong coupling enables the transition to an oscillation death (OD) regime. We used a model for light-controlled oscillators to establish the synchronization conditions and also the situation in which a tendency to produce oscillation quenching is due to a strong coupling between these oscillators [1]. According to the model, there is a critical value for which the oscillation death appears, and above this one, the oscillation death is manifested with distinctive features. We experimentally verified the model predictions concerning the transition from synchronization to oscillation death as the coupling strength increases. We studied the route to OD numerically considering

the differences of natural periods of the LCOs as well as the coupling strength. As a result of the variations of these variables, we computed the quantities characterizing the oscillation of the coupled LCOs, i.e., the amplitude and the common period or synchronization period. The above-mentioned variables characterize the transition leading to OD.
This transition exhibits among others: (i) a trend to diminish the difference of amplitudes, (ii) a kind of bursting behaviour in the signals, i.e., an increasing number of peaks, (iii) the period falls down as coupling increases. We point out that our model is based on experimental results on oscillation death, which has been carefully detailed in pulse-coupled oscillators.

References:

[1] G. Conde-Saavedra, G.M. Ramírez-Ávila, Experimental oscillation death in two mutually coupled light-controlled oscillators, Chaos, 28 (2018) 043112.

4.6 Fractal analysis of galaxy distribution

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This work performs a fractal analysis of the galaxy distribution and presents evidence that can be described as a fractal system within the redshift range of the FORS Deep Field (FDF) galaxy survey data. The fractal dimension D was derived by means of the galaxy number densities calculated by Iribarrem et al. (2012) using the FDF luminosity function parameters and absolute magnitudes obtained by Gabasch et al. (2004, 2006) in the spatially homogeneous standard cosmological model with $\Omega m_0 = 0.3$, $\Omega\Lambda_0 = 0.7$ and $H_0 = 70$ km s^{-1} Mpc^{-1}. Under the supposition

that the galaxy distribution forms a fractal system, the ratio between the differential and integral number densities γ and $\gamma*$ obtained from the red and blue FDF galaxies provides a direct method to estimate D and implies that γ and $\gamma*$ vary as power-laws with the cosmological distances, feature which provides a second method for calculating D. The luminosity distance dL , galaxy area distance dG and redshift distance dz were plotted against their respective number densities to calculate D by linear fitting. It was found that the FDF galaxy distribution is better characterized by two single fractal dimensions at successive distance ranges, that is, two scaling ranges in the fractal dimension. Two straight lines were fitted to the data, whose slopes change at z $\approx$ 1.3 or z $\approx$ 1.9 depending on the chosen cosmological distance. The average fractal dimension calculated using $\gamma*$ changes from $< D >= 1.4^{+0.7}_{-0.6}$ to $< D >= 0.5^{+1.2}_{-0.4}$ for all galaxies. Besides, D evolves with z , decreasing as the redshift increases. Small values of D at high z mean that in the past galaxies and galaxy clusters were distributed much more sparsely and the large-scale structure of the universe was then possibly dominated by voids.

4.7 Aggregation and geotaxis in Chagas disease vectors

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Chagas disease is a vector-borne disease due to the parasite *Trypanosoma cruzi* that is mainly transmitted by triatomine insects (Triatominae). These bugs live in the human neighbourhood; they aggregated in wall or roof cracks during the day and go out to feed on animal or human blood at night. Understanding the group dynamics is essential for discerning the

insects and parasite dispersion. Experiments where adults of *Triatoma infestans* were dropped at the base of an artificial wall (vertical surface) were carried out to analyse the aggregation behaviour and how the sex and the infection by *T. cruzi* affect the aggregation behaviour. Insects presented a high negative geotaxis and aggregative behaviour. Males showed a higher geotaxis and clustering than females, and infected insects than potentially weakly infected ones. An analysis of the networks formed by the clusters showed that females tend to cluster in a looser network when compared with males. Simulations demonstrated that the social part is essential in the clustering in triatomines.

4.8 Chaos and Hyperchaos of the Tarka - an Andean Musical Instrument

Flavio Ghezzi[1], *Arnaud Gérard*[1], *G. Marcelo Ramírez-Ávila*[1], *Sachiko Sakuma*[2] *and Luis Yapu-Quispe*[3]

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We explain the chaotic and hyperchaotic characteristics of the Tarka and show how the geometry of the instrument creates the conditions for this nonlinear behaviour. The generation of multiphonic sounds is analysed using spectral techniques. We confirm two particular musical behaviours and by increasing the blow pressure on different fingerings, peculiar changes from linear to nonlinear patterns are produced, leading ultimately to oscillation death.

4.9 Integrable Hierarchies, Solitons and Backlund defects

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We shall present explicitly the construction of the mKdV hierarchy in terms of graded affine algebras and show that it decomposes into positive and negative graded sub-hierarchies. Moreover we shall extend the construction of the Backlund transformation for the sinh-Gordon model to all other positive and negative odd graded equations of motion generated by the same affine algebraic structure. As an application we shall discuss the structure of integrable defects in which two solutions can be interpolated by Backlund transformation .

4.10 Extended stable equilibrium invaded by an unstable one

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Coexistence of states is an essential feature in the observation of domain walls, interfaces, shock waves, or fronts in macroscopic systems. The propagation of these nonlinear waves depends on the relative stability of the connected equilibria. In particular, one presumes a stable equilibrium to invade an unstable one, such as occur in combustion, in the spread of permanent contagious diseases, or the freezing of supercooled water. In this work, we show that an unstable state generically can invade a locally stable one in pattern-forming systems. We associate this effect to the lower free energy unstable state invading the locally stable but higher free energy state. Based on a one-dimensional model, we reveal the features

required to observe this phenomenon. The scenario fulfills in the case of a first-order spatial instability. We show that in the photoisomerization transition on a dye-doped liquid crystal cell allow us to witness the front propagation from an unstable state.

4.11 Thermodynamics of nonequilibrium phase transitions in driven Potts models

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We propose a thermodynamically consistent minimal model to study synchronization which is made of driven and globally interacting three-state units. This system exhibits at the mean-field level two bifurcations separating three dynamical phases: a single stable fixed point, a stable limit cycle indicative of synchronization, and multiple stable fixed points. These complex emergent dynamical behaviors are understood at the level of the underlying linear Markovian dynamics in terms of metastability, i.e. the appearance of gaps in the upper real part of the spectrum of the Markov generator. Stochastic thermodynamics is used to study the dissipated work across dynamical phases as well as across scales. This dissipated work is found to be reduced by the attractive interactions between the units and to nontrivially depend on the system size. When operating as a work-to-work converter, we find that the maximum power output is achieved far-from-equilibrium in the synchronization regime and that the efficiency at maximum power is surprisingly close to the linear regime prediction. [PRX 8, 031056 (2018)]

We furthermore find that the phenomenology of the three-state-model can also be observed for a whole class of driven Potts models with spin states q. It follows from thermodynamic consistency that the low- and

high-temperature phase are universal for any q. We derive the critical point that destabilizes the symmetric fixed point and generically show that all models exhibit a Hopf bifurcation. Supported by numerical studies, we claim that there are two classes of universal (thermo)dynamical properties exhibited by the Potts model depending on q: If q is even the Hopf bifurcation occurs subcricital and there are only the two high- and low-temperature phases. Conversely, if q is odd, the Hopf bifurcation occurs supercritical, that is there is an additional intermediate phase characterized by stable oscillations. [PRE 99, 022135 (2019)].

4.12 Triggering and confinement effect of 1D to 3D chaotic solitons by the interplay of periodic spatio-temporal fields

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We report the triggering of localized and confined chaos described by a general cubic order damped nonlinear Schrodinger amplitude equation containing a conjugate amplitude term, representing the time-periodic parametric driving, and a spatially periodic term, representing the external potential that cuts and confines the chaotic patterns promoted by the former, leading to trapped chaotic space-localized structures that are supported against the damping. Numerical simulations in 1+1, 1+2, and 1+3 dimensions, Lagrangian and Hamiltonian theories for continuous fields, moments method, largest Lyapunov exponents, spectral distributions, and bifurcations diagrams are used to characterize and analyze these chaotic solitons.

4.13 Mathematical considerations for the determination of a dynamical system for the description of charged massless particles

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Based on the work of the authors in [1], we review the mathematical framework that describes the dynamics of charged massless particles. The dynamics of such particles is characterized by the presence of a constraint equation that enforces the modulus of the velocity of the particle to be equal to the speed of light at any time of the evolution. Analytically, if we start with a set of initial conditions compatible with the constraints, the dynamical equations evolve the system by preserving the solution within the constrained surface. Numerically, this is not the case; the system seems to exhibit high sensitivity to the integration details, despite their refinement. A suitable modification of the original system that enlarges the field vector by incorporating the constraint as a dynamical variable proved to be more appropriate for numerical work. A similar numerical treatment performed for the massive case in the limit of zero mass and velocity closer to the speed of light shows that this case is strongly time-consuming from a computational viewpoint because of the singularity of such a limit. This latter result motivates further developments of our approach as an alternative to study the dynamics of charged ultrarelativistic particles.

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4.14 Localized Faraday patterns under heterogeneous parametric excitation

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A particular example of pattern formation in an out-of-equilibrium system is Faraday patterns. In the current work, we will show an experimental setup of a quasi-unidimensional water cell used to generate a localized injection of energy that allows visualizing Faraday patterns. The prototype model used for the theoretical calculations is the parametrically driven and damped nonlinear Schrödinger equation, which is known to describe well Faraday-instability regimes.

We characterize the zone of formation of these patterns. Theoretically, the Faraday patterns bifurcation with localized injection is supercritical. However, close the bifurcation the experimental system offers a challenges variety with results close to expectations.

4.15 A modeling approach for explaining the fireflies' synchronous behavior

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Synchronous flashing in fireflies is perhaps the first observed natural phenomenon displaying synchronization of a large ensemble. During a long time, this collective behavior was not recognized and validated as synchronous, but nowadays, it constitutes a paradigmatic example of synchronization. Despite this fact, there are not many efforts to model this astounding phenomenon realistically. One of the essential features of fireflies' synchronization is the cooperative behavior of many fireflies giving rise to the emergence of synchronization without any leader, a fact that took a long time to be recognized. A review of the main attempts to build models allowing the explanation of how and why fireflies synchronize is done. The starting point is qualitative models based on simple observations. The latter served to formulate original mathematical models enabling not only to explain fireflies' synchronization but also some other collective phenomena. Integrate-and-fire oscillators (IFOs) constitute a typical model to describe the fireflies' synchronous behavior, and they have also inspired ones to build electronic circuits with similar features and adapted to fireflies in the sense that they communicate with each other by means of light pulses. The above-mentioned electronic

circuits received the name of electronic fireflies or more technically, light-controlled oscillators (LCOs). These engines allowed a systematic study of synchronization from experimental, theoretical, and numerical viewpoints. They have also been used in a wide variety of situations ranging from simple cases of identical oscillators to scenarios where populations of dissimilar oscillators whose interaction does explain synchronization as well as the response to synchronization, a widespread phenomenon occurring in fireflies. For further details, see [1, 2].

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4.16 The Schwarzian derivative and singer's theorem

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The Schwarzian derivative appears in many areas of mathematics such as projective differential geometry and differential equations. In the dynamical systems theory it appeared for the first time independently in Singer's Theorem (1978) and Michael Herman's Doctoral Thesis (1976). Although the Schwarzian derivative now appears frequently in one-dimensional dy-

namics, it wasn't know if there is a way to motivate its definition in purely dynamical systems concepts. In this lecture we will show that Singer's Theorem is sufficient to motivate the definition of the Schwarzian derivative only from the point of view of dynamical systems. This is a joint work with Bernardo San Martin of the Universidad Católica del Norte, Chile.

4.17 Characterization of a decision taking discret social model based on complex networks

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We perform the opinion evolution analysis of a group of individuals who are under a decision making situation. This analysis is made using a mathematical model of opinion evolution which evolve in discrete steps of time and carried out through numerical simulations, where some of the parameters of the model are obtained from computational random draws. Firstly, we consider the case of a constant global external source's action on the group whose individuals do not interact; considering different connectivity types between the source and the group's members, namely, binary or continuous with constant or time dependent intensities. In this case we characterized the evolution of the opinion of the group under different values of the parameters which characterized the network. Here we made too, a comparation between the case when just the global external source interact over the individuals and the case when there is the global external source and the network of interaction between the individuals. Secondly, we consider the case of a complex network featured interaction among the individuals in addition to the action of the global

source. Afterwards, we study the case in which are present in the group the so-called intransigents, whose main characteristic is that their opinion is always opposite and do not change; thus, hindering consensus situations. Finally, we address the situation in which there are only interactions between individuals, without considering the external source, finding a sensitivity to the initial conditions in individual opinions for the evolution of the opinion state. In all cases, we analyze and compare the effects of the model variants on the opinion of the group, where the achievement or not of consensus is an essential aspect of the study.

4.18 Isochronous sets in Invariant Control Systems

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Let G be a connected Lie group with Lie algebra g and Σ = (G, D) a controllable invariant control system. A subset A ⊂ G is said to be isochronous if there exists a uniform time TA > 0 such that any two arbitrary elements in A can be connected by a positive orbit of Σ at exact time TA. In this paper, we search for classes of Lie groups G such that any Σ has the following property: there exists an increasing sequence of open neighborhoods $(Vn)n \geq 0$ of the identity in G such that the group can be decomposed in isochronous rings $Wn = Vn+1-Vn$. We characterize this property in algebraic terms and we show that three classes of Lie groups satisfy this property: completely solvable simply connected Lie groups, semisimple Lie groups and reductive Lie groups.

Chapter Abstracts: Poster presentations

The abstracts are organized alphabetically with respect to the last name of the author who presented it at LAWNP 2019. To consult for all the authors in alphabetical order, please refer to Author's Index section at the end of the document.

5.1 Topological Elastic Metamaterials

Daniel Acuña[1]

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Auxetic metamaterials are characterized by their unique property to stretch or compress in all directions when a force is applied. We focus our study in finding new properties of auxetic metamaterials by building analogies between elastic systems and condensed matter problems. In one instance we related an antiferromagnetic XY model to an auxetic material of rotating units, by comparing magnetic spins to solid rotations, as a result domain walls were found in such materials. We also modified a mechanical analogue of the SSH model such that we were able to control the position of the topologically protected mode, by extending the mechanical system.

5.2 Non-Linear Galilean Electrodynamics

Andrey Alcalá[1], *and Zui Oporto*[1]

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In this work we develop an electromagnetic theory consistent with the Galilean relativity invariance. The formalism is based on the enlargement

of the 3+1 space-time to a 4+1 space-time that permit us to encode a set of linear Galilean transformation in the extended phase-space. In addition, it is well known that in odd dimensions it is possible to include in the action a Chern-Simons term. As a result, we obtain a set of electrodynamics equations which contain a non-linear interaction between the magnetic and electric fields.

5.3 Network properties of written Spanish human language: "La Hojarasca" by Gabriel Garcia Marquez

Jhon Balaguera[1], *Carolina Latorre*[1] *and Fernando Naranjo M.*[1]

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Words in human language interact in sentences non-randomly, and allow humans to construct an astronomical variety of sentences from a limited number of discrete units. The co-occurrence of words in sentences reflects the organization of language in a subtle way that can be described in terms of a graph of word interactions. We study the topological structure of the Spanish human language, through the representation of a complex network in the novel "La Hojarasca" by Gabriel Garcia Marquez, focusing on the local properties of the network. We calculate its different statistical properties, such as the nearest neighbors and the clustering coefficient, the average distance (that is, the minimum average number of jumps that must be made from one arbitrary word to another), the degree distributions, Zipf's law, reciprocity and occurrence of binary structures in the text, that characterize the topological structure and behavior of the network. We find a composite power law behavior for both the average nearest neighbor's degree and average clustering coefficient as a function of the vertex degree. This implies the existence of different functional classes of vertices. We developed the model of empirical results based on the procedures given by A. P. Masucci and G. J. Rodgers in the Orwell's 1984.

5.4 Dynamical properties in the dissipative standard mapping

Cleber C. Bueno[1], *André L.P. Livorati*[1], *Edson D. Leonel*[1] *and Juliano A. de Oliveira*[1]

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In this work we consider the Chirikov standard mapping described by a nonlinear and two-dimensional mapping in momentum and angle variables and control parameters. Defined the model we build the phase space for the conservative system and observe a mixed structure composed by chaotic sea, periodic islands and a set of invariant spanning curves. Dissipation is introduced in the system and large chaotic attractors are observed. The maximum of the chaotic attractors as a function of the control parameters is investigated and provide a power law fitting. To characterise the chaotic behavior the Lyapunov exponents are considered.

5.5 A new seed found in an integer sequence

Roy O.E. Bustos-Espinoza[1] *and G. Marcelo Ramírez-Ávila*[1]

[1]*Instituto de Investigaciones Físicas, Universidad Mayor de San Andrés, Bolivia*

We found a new integer sequence: 3, 5, 6, 10, 12, 20, 24, 20, 48, 80, 96, 160, ... that comes from a bifurcation cascade into the parameter plane, exiting a chaotic window and going to another chaotic region in a system of two coupled logistic maps whose dynamical behavior is done in terms of their integer periodicities [1]. By this way we justify a new seed in the K. Brokhaus sequence reported in the On-line Encyclopedia of Integer Sequences (OEIS) [2]. We proposed the same recurrent relation: $a(n) = 2a(n-2)$ for $n > 2$ with new seeds: $a(1) = 3$ and $a(2) = 5$.

References:

[1] R.O.E. Bustos-Espinoza and G.M. Ramírez-Ávila, Synchronization conditions of coupled maps using periodicities, The European Physical Journal Special Topics, 225, 2697-2705, (2016).

[2] THE ON-LINE ENCYCLOPEDIA OF INTEGER SEQUENCES

5.6 Experimental study of synchronization in coupled electronically equivalent logistic maps forming motifs

Luis Cabezas-Tito[1], *Rodolfo Gutierrez-Barrón*[2], *Roy O.E. Bustos-Espinoza*[3] *and G. Marcelo Ramírez-Ávila*[3]

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We implemented electronic logistic maps like those used by L'her et al. [1]. We worked with sets of three almost identical oscillators for the two possible motifs working with three mutually coupled oscillators. The aim is to verify which of the motifs enhance synchronous behavior by determining the synchronization region experimentally. The latter is obtained by computing the value of the synchronicity factor in the same line of the method used by Bustos-Espinoza and Ramírez Avila [2].

References:

[1] L'Her A, Amil P., Rubido N., Marti A.C., and Cabeza C., Electronically-implemented coupled logistic maps, The European Physical Journal B. (1996).

[2] Bustos-Espinoza R.O.E. and Ramírez-Ávila G.M. Synchronization

conditions of coupled maps using periodicities, The European Physical Journal Special Topics, (2016).

5.7 Cancerous cells population dynamics analysis using a model with radiosensitivity

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This work describes the population dynamics of cancerous cells when they interact with normal cells as well as with the effector cells that are related to the immunological response. The model is based on logistic equations describing the growth of the populations of cancerous and normal cells, the Lotka-Volterra model for competitive species including the radiation effects on both cells, and the Michaelis-Menten equation describing the interaction among the cancerous and effector cells. The parameters of the model are in a relationship with the interactions between the different types of cells and in particular on the effects on the inactivation of the cancerous cells due to the action of the normal ones and the transformation of the normal cells caused by the presence of tumoral ones. We also consider the radiosensitivity of each type of cells. We performed a linear stability analysis of our model, determining volumes of stability in several projections of the parameter space. The model exhibits a great dynamical richness going from fixed points to chaotic behaviors. We took into consideration several regions of the parameter space looking for parameter

values leading to the situation in which the radiation tends to eliminate the tumoral cells with no or slight modifications on the populations of normal cells. The latter could constitute an important application concerning effective radiotherapy treatment.

5.8 Correlation of movement between residues located in the disordered and ordinate areas, by means of classical molecular dynamics

Flor Cardenas[1], *Dayanne Pamo*[1] *and David Ychocan*[1]

[1] *Universidad Nacional de San Agustin. Arequipa, Peru*

In the present work, the possible correlation of the movement between the residues located in the disordered and orderly areas of the protein structures will be sought. For this, protein dynamics simulations will be carried out, through classical molecular dynamics. A series of simulations will be carried out for each protein under study, to determine the temporal evolution of the protein structure. For the structure stored along the simulation path, the set of quaternions that describe each of its residues will be determined. Subsequently, the distance between the quaternions of homologous residues will be measured and these differences will be analyzed with deep learning methods to find possible correlations between the movements of the protein residues.

5.9 Dynamics of bubble-like fluxons under the action of localized forces

Alicia G. Castro Montes[1], *Mónica A. García-Ñustes*[1] *and Juan F. Marín*[2]

[1] *Instituto de Física, Pontificia Universidad Católica de Valparaíso, Chile*

[2] *Departamento de Física, Universidad de Santiago de Chile, Santiago, Chile*

In condensed matter systems, solitons have become relevant due to their particle-like properties. In particular, they have turned fundamental to de-

scribe fluxons in Josephson junctions (JJ's). In this work, we investigate analytically and numerically the stability of bubble-like fluxons in the 2D sine-Gordon system under the action of a coaxial dipole current. Through a linear stability analysis, we reduce the problem to a Schrödinger-like equation with a modified Pöschl-Teller potential, solving the problem exactly. We provide a theoretical description of the response of bubble fluxons to the coaxial dipole current, finding a stabilization domain, emergence of internal modes, and bubble break up. We also explore the effect of a uniform external microwave field on the dynamics.

5.10 An approach to FLRW-cosmology from a dynamical system perspective

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In this work we revised the Friedmann–Lemaître–Robertson–Walker cosmology from the approach of dynamical systems. We start by a derivation of the dynamical equations from a dimensionally reduced Lagrangian density of the full Einstein-Hilbert Action. The dynamical system can be characterized by a set of three non-linear equations plus a constraint. By a suitable manipulation of the system, it is possible to rewrite the equations as a set of two equations that resemble in some respects a Lotka-Volterra system.

5.11 Cities of knowledge, municipalities and environment

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How to generate knowledge, science, technology, innovation and also

integral and sustainable development for Bolivia, is the job of the municipalities. City of knowledge We are looking for reply in Bolivia some of the small knowledge cities of other countries and getting the better conditions for the scientific investigation. Where do we want to get with the cities of knowledge?

1. All of then go to have a science advance, technology and innovation.
2. What for?
3. For whom it is?

What for?

For getting knowledge, technology and innovation, so the actions that solve the problems as the most important needs, to get the sustainable development of their countries.

FOR WHOM IT IS?

- For the focus population
- For getting better life conditions
- For a wellness and a life quality

Taking these thoughts, a city of knowledge could be implanted anywhere. In Bolivia, we think the best place is Cochabamba city.

WHAT WE NEED FOR THIS PROJECT?

We need to identify which are the real inputs or primary materials to help the job of the cities of knowledge.

HOW TO IDENTIFY THE PRIMARY MATERIALS FOR A CITY OF KNOWLEDGE?

It is very important to identify and get the primary materials, main need from the municipalities and communities through a real combination. Human resources + Natural resources + economic resources These problems and need that have been identified are the primary materials for building a city of knowledge, for the achievement of goals. If we don´t do this, the

project will not be able to be supported.

OBJECTIVES OF THE CITY OF KNOWLEDGE IN BOLIVIA

- Integral and sustainable development in Bolivia, that also would be environmental friendly.
- Good quality Job creation
- Eradication of poverty
- Wellness in Bolivian people

For example, in Vancouver, Canada, there is a dam which generates energy but it is completely friendly with the environment. Also, Portland in USA, has a building which has been done with all the commodities, services and vegetation program for inside and outside of the place. It looks so natural.

HOW TO ACHIEVE THE GOALS OF THE CITY OF KNOWLEDGE IN BOLIVIA?

- The BACA suggests a strategic plan based on getting the best combination of human, natural and economic resources.
- This project should be done trough:
- Small planning method, participation of many groups, echo sustainable, and without a social exclusion.
- The knowledge, science, technology and innovation will be the most important parts for getting the municipals development; all of them will achieve the integral and sustainable development of Bolivia.

ACHIEVEMENT OF GOALS

We will have a country with integral and sustainable development, environmental friendly. It will be called, BOLIVIA.

5.12 Periodicity Characterized Synchronization in threesome of Rulkov neurons

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We studied synchronization as a function of coupling strength in threesome Rulkov neurons featured by their periodicities, and considering electrically and bidirectional coupling. Firstly, we determined the dynamical behavior of a single neuron by using its periodicities into the parameter plane. we identified the typical behavior of spiking-bursting in several regions of this plane. Several basins of attraction for the Rulkov model were obtained exhibiting multistability. We worked with identical and different neurons but with the same periodicity. We found that the heterogeneous configuration enhances synchronization; aspect that was verified by analyzing the time series of the slow variable.

5.13 Structure of the parameter space for a family of two-dimensional mappings

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The structure of the parameter plane for a family of two dimensional, nonlinear and area contracting mappings is investigated. 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.

Thanks FAPESP (2018/14685-9) and CNPq (303242/2018-3, 421254/2016-5, 311105/2015-7).

References:

[1] Juliano A. de Oliveira, Leonardo T. Montero, Diogo R. da Costa, J.A. Méndez-Bermúdez, Rene O. Medrano-T and Edson D. Leonel. Chaos, 29, 053114, (2019).

5.14 Frailty characterization with *C. elegans* in ageing and expossure to stressors

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A biological system is characterized by a set of different interdependent scales which interact non-linearly. It has been therefore proposed that the dynamics of physiological variables reflect the underlying modulation mechanisms. Among all physiological variables in humans, heart rate

variability (HRV) is the most studied one and has been proved to serve as an independent predictor for some chronic degenerative diseases. Our research team proposes *Caenorhabditis elegans* as an animal model to explore the relationship between the dynamics of physiological variables and its underlying modulation mechanisms. Hereby we aim to test the hypothesis that the variability of the pharyngeal pumping could be a relevant index of functional decline in exposure to stressors and ageing in this organism. In *C. elegans*, feeding is achieved through pharyngeal muscular contractions (pharyngeal pumping) controlled by pacemaker neurons. In view of its neurogenic nature, the *C. elegans* pharynx can be used as a simplified model of the human heart. Furthermore, the *C. elegans* lifespan is only around two weeks; hence physiological alterations can be visualized over the course of aging. Age-related changes in tissue morphology and function, and a decline in *C. elegans* health are strongly correlated with a reduction in pharyngeal pumping rate (number of pumps/ total recording time) and thus with a decline in survival probability. Traditionally pharyngeal pumping has been assessed by eye and therefore the underlying variability has not yet been taken into account.

5.15 Time series for a meteorological database of the Tambo Quemado station

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Using a meteorological database of the variables: pressure, humidity, temperature, solar radiation intensity, wind speed, and direction wind from the Tambo Quemado station (Lat (S) 18o 17’ 21” lon (W) 69o

0’ 17” Altitud 4681 masl) going from March 2006 to August 2007, we performed a time series analysis of each variable. Firstly, we obtain the FFT to determine the existence of some regular oscillatory behaviour. The variables related to wind resulted the more complicated to analyze; thus, we take the problem using nonlinear tools for time series analysis. In particular, we use autocorrelation, embedding techniques and recurrence quantification analysis. The reconstruction of the phase space gives us the possibility to characterize the caotic behavior of some of the above mentioned variables.

5.16 Complexity outcomes from the musical trios of W.A. Mozart and M. Feldman

Guillermo Daniel Leonardini Gutiérrez[1], *Mizky Bernal Miranda*[1], *Guillermina Miranda Torrez*[2] *and G. Marcelo Ramírez-Ávila*[3]

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We apply nonlinear dynamics tools to analyze musical works, in this particular case, the trios of the composers W. A. Mozart (1756-1791) and M. Feldman (1926-1987). Mozart is one of the most important composers of the Classical period. His work is characterized by its symmetry, formal perfection and a mathematical organization. On the other hand, Feldman is, in turn, an important composer of the XX century, which has a nonlinear discourse and great temporal extension; features that move it away from the classical discourse. From the Mozart’s trios (KV. 10, 11, 12, 13, 14, 15, 496 and 564) and Feldman’s (For Philip Guston and Three Voices), numerical series were generated representing

the durations of event interventions sounds of each work. Subsequently, we constructed symbolic sequences with the aim to perform an analysis of symbolic dynamics that allowed us to find power-laws in what concerns the interventions of each of the instruments combinations. In parallel, we performed descriptive statistical analysis to obtain data distributions and frequency histograms. Through the Data Cluster, the first results were obtained: the works could be grouped by the level of similarity they have, quantitatively demonstrating the differences in the works of each composer; also, a model of the Mozart time series was obtained. Finally, it was established that the composition of these works responds to a complex phenomenon, in which the relations of the instruments with each other and with silence generate complexity in the composition.

5.17 Experimental study of the rotating hoop with bead

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A sphere contained in a rotating ring is a known and simple nonlinear system that shows vast dynamic behavior. Although the theoretical treatment of the system, particularly referring to the control parameter – angular velocity – is frequent, it is not common to find and experimental arrangement that allows for bifurcation and stability analysis. This work shows the characterization of the system with a simple experimental setup and under different established situations. The assembled experiment allows obtaining the bifurcation diagram of the control parameter predicted by the theory, when working with a single sphere. Additionally, it allows the study of the system in the situation in which there is more than one sphere, verifying the equiprobable behavior of the new equilibrium point. Some interesting results were found in particular cases when treatment

with various spheres and fluids is performed.

5.18 eEvolution: a bottom up approach

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The theory of evolution by natural selection, first formulated by Darwin in 1859, is the process by which organisms change over time as a result of changes in heritable physical or behavioral traits. In this study we aimed at observing evolutionary processes of natural selection and genetic drift using a model without artificial intervening selection. In our model, time and space are discrete and a single organism can interact with its environment as well as other organisms. The environment is comprised of a set of resources with specific decay and diffusion rates (e.g. ATP, fat, smell). Each organism possesses an internal state and the ability to perceive its immediate surrounding environment. The internal state is determined by possessed resources and a short memory of previous time steps. In each time step, an individual performs an action which influences themselves as well as their environment in the following times. Their basic actions consist of movement, reproduction and consumption. These actions are decided with an artificial neural network, which is specific to an individual. The factors that contribute to the decision consist of their internal state as well as the state of their immediate environment. When they reproduce, there are minor mutations within each generation,

causing genetic drift and speciation in the long term. In our model we considered two landscape configurations: homogeneous and island-like landscapes. In the homogeneous landscape the resources are plentiful and evenly distributed, while in the island-like landscape, nutrients are concentrated in particular locations with different sizes and distances scattered across the landscape. We hypothesized a lower genetic drift and natural selection in a homogeneous compared with the island-like landscape. Within a relatively short period of time, we were able to observe and quantify genetic drift. On the final diversified populations we conducted statistical analyses on genotypic and phenotypic traits.

5.19 Application of the Entropy of Approximation for the nonlinear characterization in patients with Chagas disease

Miriam Manrique[1]

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Chagas Disease American trypanosomiasis is caused by a flagellated parasite: *Trypanosoma cruzi*, transmission by an insect of the genus *Triatoma*, and also by blood transfusions. In Latin America, the number of people infected is approximately 6 million, with a population exposed to the risk of infection of 550000. It is our interest to develop a non-invasive and low-cost methodology capable of detecting any early alteration of cardiac production by *T. cruzi*. For this, we analyzed the 24-hour Holter ECG records in 107 patients with ECG abnormalities (CH2), 102 patients without ECG abnormalities (CH1) who had positive serological results for Chagas disease and 83 volunteers without positive serological results. Chagas disease (CONTROL). We used the approximate entropy to quantify the regularity of the electrocardiograms (ECG) in the three groups. We analyzed 288 ECG segments per patient. Significant differences were found between the CONTROL and CH2 groups, which was used to stratify

the risk in the CH1 group.

5.20 Determination of the correlation of movement between different sections of the protein structure analyzing the conformations by means of nuclear magnetic resonance

Jorge Mendoza[1], *Henry Quispe*[1] *and Luis Tito*[1]

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In this research work we intend to establish a methodology, which in an unambiguous way, allows us to identify the correlation of movement between different sections of the structure of a protein. For this, the different conformations given for the same protein determined by means of nuclear magnetic resonance will be analyzed. Consequently, the quaternion associated with each residue of a given protein will be determined and then the distance between the quaternions corresponding to homologous residues in different structures will be measured. When analyzing these differences with machine learning methods, we expect to find a correlation between the dynamics of the different residues in the protein.

5.21 Deep Learning Image Recognition Algorithms used to classify dynamical behaviours

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Deep Learning techniques have improved notoriously in the last decade. In particular, Neural Networks with adequate training are been widely used for image recognition and classifying objects. This poster shows how Neural Networks can analyze phase portraits through image recog-

nition in order to classify different dynamical behaviours. Hence, chaos, homoclinic orbits or other behaviours can be classified by the Neural Network. This could give a new tool for data analysis.

5.22 Bifurcation fringe in the space of concentrations for the Belousov-Zhabotinsky reaction

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We carried out experiments concerning the Belousov-Zhabotinsky (BZ) reaction in a closed reactor working with a pH of 0.097. The Oregonator model and an extended Field-Köros-Noyes mechanism for the organic set of reactions provide us the explicit form of the two system parameters that depend on the relative proportion of reagents. Although some kinetic values play the role of scaling parameters, from an experimental point of view both parameters subtend a "space of concentrations." We prepared different reagents reference concentrations (potassium bromate and malonic acid at constant bromomalonic acid) to obtain the kinetic series by means of spectroscopic measure of Ce(IV)-concentration at a wavelength of 400 nm. The classification of the dynamics that results from the reference concentrations allowed us to identify two regions of states in the space of concentrations: one containing the oscillatory regime and the other with the stationary states, both separated by a fringe that is the counterpart of the Hopf bifurcation curve in the parameter space predicted by the Oregonator. We also observed the modification of the bifurcation fringe with increasing pH value; the dependence of the Hopf bifurcation curve with respect to the parameter related to the acidity justifies the BZ reaction inhibitory tendency as pH increases. Finally, we report the numerical study of the complete synchronization of two identical oscillators

modeled by the Oregonator with diffusive and bidirectional coupling; we propose a structural dependence of the synchronized system with respect to the coupling coefficient.

5.23 Design of a heterogeneous substrate for Faraday waves formation in a water cell

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In the context of pattern formation studies, specifically on Faraday Waves, we have designed and assembled a new experimental setup, which, due to its versatility, can adapt to different configurations given by specific requirements and measurements. This setup consists of a quasi-one-dimensional liquid column vertically perturbed under a localized injection of energy. We vary the geometry of the bottom, initially, with triangular and rectangular reliefs to study how pattern formation is affected by them.

5.24 Bekenstein Bounds and Nonlinear Electrodynamics

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Bekenstein bounds are assumed to be of universal nature, therefore they can offer us a guiding path towards discerning between alternative theories for fundamental interactions. In this work, we analyze the validity of Bekenstein bounds in the context of arbitrary nonlinear electrodynamics; as well as offer arguments for these bounds not to be a sufficient condition for causality. Finally, we set the ground for deriving new bounds assuming a Born-Infeld charge being absorbed by a Schwarzschild black hole.

5.25 Study of high mountain neutron flux produced by cosmic rays through Monte Carlo simulations

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We work on the characterization of the atmosphere, considering it as a nonlinear system. Once characterized, we make the prediction of neutron flux in the Chacaltaya mountain under Monte Carlo simulations. We take into account the pressure, temperature and density of the air, together with concentrations of: vapor of H2O, CO, CO2, N2 and O3. A validation of the simulation results is also done through experimental measurements.

5.26 Chaotic one-dimensional domains induced by periodic potentials in normal-dispersion fiber lasers

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We investigate numerically the effects of external time-periodic potentials on time-localized perturbations to the amplitude of electromagnetic waves propagating in normal-dispersion fiber lasers which are described by the complex Ginzburg-Landau equation. Two main effects were found: The formation of domains enclosed by two maxima of the external periodic field and the generation of a chaotic behavior of these domains in the region of relatively high amplitudes and low frequencies of the external fields. Maps and bifurcation diagrams of the largest Lyapunov exponent and moments, such as energy and momentum, are also provided for

different values of the amplitude and frequency of such external potentials. Published by AIP Publishing. https://doi.org/10.1063/1.5006919

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[1] Urzagasti, D., Vargas, B.A., and Quispe-Flores, L.A. Chaotic one-dimensional domains induced by periodic potentials in normal-dispersion fiber lasers. Chaos: An Interdisciplinary Journal of Nonlinear Science, 27(10), 103116 (2017).

5.27 Study of fixed dipoles with fractal symmetry

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A fixed dipole with fractal symmetry was set up using a circle generation computational tool. The arrangement was composed of either 8 or 9 circles that repeated sequentially. The dielectric field generated by this arrangement was analysed. Different points of symmetry were observed and were correlated to the stability levels of the arrangement.

5.28 Localized modes in two-dimensional octagonal-diamond lattices

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Two-dimensional octagonal-diamond (OD) atomic lattices have been explored in recent times to study phenomena related to topological phase transitions induced by spin-orbit interaction and gauge fields [1], and magnetic phases and metal-insulator transitions with Hubbard interaction [2,3]. It can lead to the appearance of nontrivial nearly flat band states with particular topological properties [4]. Here we study the octagonal-diamond photonic lattice formed of linearly coupled waveguides, proposed by [4] as a possible experimental realization of an artificial flat-band system. We investigated analytically and numerically the existence and stability of linear and nonlinear localized modes in a two-dimensional OD lattice. The primitive cell consists of four sites, linearly coupled with each other with the same coupling constant, including two diagonal couplings. The eigenvalue spectrum of the linear lattice consists of two flat bands and two dispersive bands [4]. The upper dispersive band intersects the upper flat band in the middle of the Brillouin zone, as well as the second flat band at the end of the Brillouin zone. In the linear case, there are two types of localized linear solutions, which are composed of eight sites each, having either monomer (+ - + - + - + -) or dimer (+ + - - + + - -) staggered phase structure [4]. In the presence of Kerr nonlinearity, both focusing and defocusing, compacton-like solutions [5] are unstable due to intersections of the upper dispersive band and the flat bands. We are currently in the process of finding soliton solutions in the frequency gaps occurring between the flat bands and the isolated dispersive bands.

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5.29 Experimental obtention of galleries of attractors for Chua's and RL-Diode circuits and the study of synchronization in mutually coupled oscillators

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We obtained experimentally a vast gallery of attractors for Chua's and RL-Diode circuits. Using mutual coupling, we studied the possibility of synchronization in both of synchronization for two oscillators and then expand our system to several oscillators.

5.30 Modelling the Fishers-Centolla System Dynamics

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Chapter Abstracts: Divulgation talks

6.1 "¿Es necesario hablar de género en Ciencia?" (in spanish)

María Fabiana Laguna[1]

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6.2 Introducción al caos determinista y el problema de los 3 cuerpos (in spanish)

Miguel A.F. Sanjuan[1]

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6.3 Analisis de series de datos temporales con aplicaciones interdisciplinarias (al clima, el cerebro y las olas gigantes) (in spanish)

Cristina Masoller[1]

[1]*Universidad Politecnica de Catalunya, Spain*

6.4 Dinámica unicelular y poblacional de la resistencia a antibióticos en bacterias (in spanish)

Maximino Aldana González[1]

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