MEDYFINOL 2016

XIX Conference on Nonequilibrium Statistical Mechanics and Nonlinear Physics

Valdivia, Chile.
December 5th–9th, 2016

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History

MEDYFINOL is a traditional and regular meeting of the statistical and nonlinear physics community in Latin-America. The XIX Conference follows a series of meetings that took place in Maceió, Brazil (2014); Santiago de Chile, Chile (2012); Punta del Este, Uruguay (2008); Mar del Plata, Argentina (2006); La Serena, Chile (2004); Colonia del Sacramento, Uruguay (2002); Córdoba, Argentina (1999); Canela, Brazil (1997); Tucumán, Argentina (1996); San Carlos de Bariloche, Argentina (1995); Montevideo, Uruguay (1994); Mar del Plata, Argentina (1993); Mar del Plata, Argentina (1991); Santiago de Chile, Chile (1990); Puerto Iguazú, Argentina (1989); Mar del Plata, Argentina (1988); Luján, Argentina (1987), and Luján, Argentina (1986).

Statistical and nonlinear physics are multidisciplinary research areas with many applications in biology, economy, sociology, engineering sciences, chemistry, etc. The purposes of the MEDYFINOL meetings are to keep updated the scientific community on the new developments and tendencies in the statistical mechanics and nonlinear dynamical fields, to incentive collaborative international science programs, and to identify and discuss the most relevant advances in the area.

The success of the MEDYFINOL meetings can be attributed to the presence of eminent speakers; the high quality contributed papers, as well as significant student participation.

More information about past versions of MEDYFINOL can be found at `http://www.medyfinol.org`.

Acknowledgements

- Universidad de los Andes
- Universidad Austral de Chile
- Universidad Federal de Alagoas
- Instituto Tecnológico de Buenos Aires
- Universidad Nacional de Mar del Plata

Useful Information

Venue

MEDYFINOL 2016 will be held at:

Villa del Río Hotel & Marina
Av. España 1025, Valdivia, Chile
Phone: + 56 63 221 6292
E-mail: hotel@villadelrio.cl
Website: `http://www.villadelrio.cl`

Packed lunches will be served in the hotel to registered participants on Monday, Tuesday, and Thursday.

Plenary talks and most invited talks will take place in Salón 'Provincial'. For parallel sessions of invited talks we will also use Salón 'Los Conquistadores'.

Excursion

The conference includes an excursion that will take place on Wednesday afternoon. Since the number of seats in the bus are limited we encourage the interested participants to reserve a seat by sending an email to the organizer Jaime Cisternas: jecisternas@miuandes.cl or directly at the registration desk.

Parque Oncol is a natural reserve located 32 km (20 mi) from the city of Valdivia, Chile. The park has an area of 7.54 km2 (3 sq mi) of which most lies on Cerro Oncol (715 m), the highest peak of the Valdivian Coast Range, but is only 5 km (3 mi) from the coast. Oncol Park is located in an area of 15 km2 (6 sq mi) of continuous Valdivian temperate rain forest.

From the peak of Cerro Oncol it is possible to see Llaima Volcano, Villarrica Volcano and even Mount Tronador on the international border of Chile and Argentina. The park is property of the wood pulp enterprise Celulosa Arauco y Constitución.

This excursion includes a intermediate-level hike with a local guide and a snack at one of the park facilities.

More information: `http://www.parqueoncol.cl`

We give thanks to Celulosa Arauco for its kind collaboration to Medyfinol.

Wifi

Details are going to be provided at registration.

Posterflash

Posters are going to be displayed for the full duration of the conference in a hall adjacent to the conference room, where the coffee breaks will be served. Please use the A0 size and portrait orientation.

On Tuesday and Wednesday the authors of posters will have a chance to present a brief summary of their work in front of the public. If you want to take advantage of this opportunity, please prepare one or two slides (a pdf or ppt file) and send them to Carlos Cartes ccartes@gmail.com.

Public Lecture

This year the Public Lecture is given by Prof. Jürgen Kurths of the Potsdam Institute for Climate Impact Research on Monday late afternoon. The title is **Climate Networks and Extreme Events**. The abstract with references is included in this booklet.

This lecture will take place in the Auditorioum "Prof. Hugo Campos" of the Sciences Faculty at Campus Isla Teja of Universidad Austral. A reception will be served afterwards. Transportation between the hotel and the university will be provided.

Welcome

to the XIX MEDYFINOL 2016 in Valdivia

We are looking forward to a week of interesting talks, poster presentations, and discussions about topics from the entire field of Statistical Mechanics and Nonlinear and Nonequilibrium Physics. For 30 years MEDYFINOL has been a key forum in the South Cone for the exchange of ideas about a broad spectrum of physical and multidisciplinary phenomena. We hope that this year's conference will be a great venue to communicate your scientific work and stimulate new collaborations.

Wishing you all an exciting week here in Valdivia,

Orazio Descalzi on behalf of the organizing team.

Schedule

Abstracts

Synchronization of coupled noisy oscillators: Coarse graining from continuous to discrete phases

5 Dec
10:00

Katja Lindenberg

Department of Chemistry and Biochemistry, University of California, San Diego, La Jolla, USA

The theoretical description of synchronization phenomena often relies on coupled units of continuous time noisy Markov chains with a small number of states in each unit. It is frequently assumed, either explicitly or implicitly, that coupled discrete-state noisy Markov units can be used to model mathematically more complex coupled noisy continuous phase oscillators. In this work we explore conditions that justify this assumption by coarse graining continuous phase units. In particular, we determine the minimum number of states necessary to justify this correspondence for Kuramoto-like oscillators.

The $(5+1)$ infinities for space-time coupled Lévy walks

5 Dec
10:35

Tony Albers and Günter Radons

Komplexe Systeme und Nichtlineare Dynamik, Technische Universität Chemnitz, Chemnitz, Germany

We recently detected and analyzed in detail the phenomenon of weak ergodicity breaking (WEB), i.e. the inequivalence of ensemble- and time-averaged squared displacements, for randomly accelerated particles (RAP) [1]. These results, which are relevant for anomalous chaotic diffusion in Hamiltonian systems, for passive tracer transport in turbulent flows, and many other systems showing momentum diffusion, motivated us to study some related models. One of them, namely the space-time correlated Lévy walk, introduced in the context of turbulence [2], is considered as physically most relevant due to the finite velocities appearing in its definition. Therefore, after showing the basic WEB results for RAP, the WEB related "phase diagram", obtained by varying the two defining exponents of the Lvy walk, is discussed in detail. Apart from the well-known boundary between stationary and non-stationary increments indicated by a diverging mean residence time, we find even in the stationary regime five more transition lines, each associated with a diverging quantity. These lines intersect and divide the stationary regime into nine different "phases", each characterized by certain combinations of diverging and non-diverging characteristic quantities.

[1] T. Albers and G. Radons, Physical Review Letters **113**, 184101 (2014)
[2] M. Shlesinger, B. West, and J. Klafter, Physical Review Letters **58**, 1100 (1987)

On the Interaction of Dissipative Solitons: Selected Recent Developments

5 Dec
11:50

Helmut R. Brand[1] and Orazio Descalzi [2]

[1] University of Bayreuth, 95440 Bayreuth, Germany,
[2] Complex Systems Group, Facultad de Ingeniería y Ciencias Aplicadas, Universidad de los Andes, Santiago, Chile

The investigation of the interaction of stable localized solutions (dissipative solitons) started over 25 years ago when it was shown [1] that these objects can annihilate or interpenetrate depending on the cross coupling strength of counter-propagating waves. Shortly thereafter this research was generalized to two spatial dimensions (compare [2] and references therein).

A long standing puzzle in the field of pattern formation has been the experimental observation of the partial annihilation of pulses in binary fluid convection [3] and and during CO oxidation in surface reactions [4,5]. It was shown that already a small amount of additive noise can account for the experimental observations [6]. The mechanism will be elucidated in the presentation.

We will address in particular two recent developments. It turns out that the results of the interaction between quasi-one-dimensional dissipative solitons, which has been studied first for temporally asymptotic initial conditions [7], are changed qualitatively for intial conditions which are not yet temporally asympototic [8]. For sufficiently small approach velocity and sufficiently large values of cross-coupling we demonstrate that there are non-unique results for the outcome of collisions. We show that these non-unique results can be traced back to a modulation instability along the crest of the quasi-one- dimensional objects.

For the interaction of exploding dissipative solitons we demonstrate [9] that six different outcomes can occur as a function of the nonlinear cross-coupling between cunter- propagating waves. These include complete interpenetration, one compound exploding DS as well as four types of compound DSs.

[1] H.R. Brand and R. J. Deissler, Phys. Rev. Lett. 63, 2801 1989).
[2] R.J. Deissler and H.R. Brand, Phys. Rev. E 51, R852 (1995).
[3] P. Kolodner, Phys. Rev. A 44, 6466 (1991).
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[5] A. von Oertzen, A.S. Mikhailov, H.H. Rotermund, G. Ertl, J. Chem Phys. B 102, 4966 (1998).
[6] O. Descalzi, J. Cisternas, D. Escaff, H.R. Brand, Phys. Rev. Lett. 102, 188302 (2009).
[7] O. Descalzi, H.R. Brand, Phys. Rev. E 87, 022915 (2013).
[8] O. Descalzi, H.R. Brand, Phil. Trans. R. Soc. A 373, 20150115 (2015).
[9] O. Descalzi, H.R. Brand, Eur. Phys. J. B 88, 219 (2015).

The Riddles of Subsurface Oxygen in Pattern Formation during CO-oxidation on Platinum

5 Dec
12:25

H.H. Rotermund and P. Sadeghi

Department of Physics and Atmospheric Science Dalhousie University, Halifax, Canada

Even in the earliest publications in 1990 on pattern formation during CO oxidation utilizing PEEM, clear signs of an additional, different third reactant species became quite obvious. Only in 1992, in the PhD-thesis by Alexander von Oertzen, [1] observations of extreme bright areas during pattern formation were directly mentioned, grey scale values presented and to quote the author "in a daring interpretation these brightened spots could be associated with subsurface oxygen". An example of this third kind of reactant imaged with PEEM is presented in the figure below from [2].

Although much is now understood about the conditions for subsurface oxygen on Pt, still many questions remain open twenty years later. In a recent study Sadeghi et al. observed the inversion of anisotropy in spatiotemporal reaction-diffusion patterns at low to intermediate pressures during the catalytic oxidation of CO on Pt(110) utilizing two different surface imaging methods (RAM and PEEM) [2]. The change in anisotropy was found to depend mainly on the total reactant dosage, but no correlation between the rate of the inversion process and the reaction temperature was observed. Analyzing a set of experiments conducted at a constant oxygen partial pressure and within a small temperature range showed a strong correlation between the appearance of subsurface oxygen and the appearance of isotropic patterns. This clear correlation is still not understood and further experiments and simulations are needed to solve this riddle. In addition, a completely different interpretation of those bright spots will be discussed.

[1] A.v. Oertzen, Untersuchung der Diffusion von Adsorbaten mittels Photoemissions-Elektronen-mikroskopie (PEEM), Freie Universität Berlin (1993).
[2] H.H. Rotermund, Investigation of dynamic processes in adsorbed layers by photoemission electron microscopy (PEEM). Surf. Sci., 283, 87-100 (1993).
[3] P. Sadeghi, C. Punckt, H. H. Rotermund, Inversion of Pattern Anisotropy during CO Oxidation on Pt(110) Correlated with Appearance of Subsurface Oxygen, J. Phys. Chem. C 116, 4686-4691 (2012).

Instabilities in conducting fluids excited by slowly time-dependent magnetic fields: from the lab to the MRI

5 Dec
14:00

I. Cortés-Domínguez, M.A. Fernández-Seara, N. Pérez, and Javier Burguete
Departamento de Física y Matemática Aplicada, Universidad de Navarra, Navarra, Spain

Fluid dynamics has been studied for decades as the central point of many physical processes, and many different experimental setups have been analysed. The objective of this work is the study and analysis of instabilities in two related systems: on the one hand, the effects of weak magnetic fields in a liquid metal layer. On the other hand, the effects of the MRI test in the inner ear. If these are two different problems (each of them with its scientific value), why study them together? Both approaches are forced by the same mechanism, the MHD forces.

We will start with a discussion of the instabilities that appear in a small volume of a liquid metal with a weak magnetic field. We have characterized the phase space and the two competing mechanisms. Our instability threshold appears for parameter values two order of magnitude lower than in previous studies. On the second part we will analyze the situation of a weak conductor (an electrolyte) in a strong magnetic field: the inner ear in a MRI device. We have determined that these MHD effects cannot be neglected and open a new door to new approaches to diagnose inner ear diseases.

Vertical vortices in thermoconvective instabilities

5 Dec
14:35

Henar Herrero, Damián Castaño and María Cruz Navarro
Departamento de Matemáticas, Universidad de Castilla-La Mancha, 13071 Ciudad Real, Spain

There are different atmospheric phenomena with the common factor of vertical vortex dynamics, from small events such as dust devils and tornadoes, to large events as hurricanes and cyclones. Thermal convection is one of the relevant processes involved in their formation and evolution. In this work the incompressible Navier Stokes equations under the Boussinesq approximation coupled with the heat equation considering a nonhomogeneous heating from below are solved numerically with a fully 3D temporal temporal code. Vertical vortices are obtained after an instability with zero wave number and azimuthal velocity different from zero. Depending on different parameters of the problem a central eye is formed, the structure becomes tilted or subvortices are formed in a route to chaos. These features are related to those of atmospheric vertical vortices.

The Brezis-Nirenberg problem on $\mathbb{S}^N$, in spaces of fractional dimension

5 Dec
15:30

Rafael D. Benguria[1] and Soledad Benguria[2]

[1] Instituto de Física, Pontificia Universidad Católica de Chile,
[2] Department of Mathematics, University of Wisconsin, Madison

We consider the nonlinear eigenvalue problem,

$$-\Delta_{\mathbb{S}^n} u = \lambda u + |u|^{4/(n-2)} u$$

with $u \in H_0^1(\Omega)$, where Ω is a geodesic ball in $\mathbb{S}^n$. In dimension 3, this problem was considered by Bandle and Benguria. For positive radial solutions of this problem one is led to an ordinary differential equation (ODE) that still makes sense when n is a real rather than a natural number. Here we consider precisely that situation with $2 < n < 4$. Our main result is that in this case one has a positive solution if and only if $\lambda \geq -n(n-2)/4$ is such that

$$\frac{1}{4}[(2\ell_2 + 1)^2 - (n-1)^2] < \lambda < \frac{1}{4}[(2\ell_1 + 1)^2 - (n-1)^2]$$

where ℓ_1 (respectively ℓ_2) is the first positive value of ℓ for which the associated Legendre function $P_\ell^{(2-n)/2}(\cos\theta_1)$ (respectively $P_\ell^{(n-2)/2}(\cos\theta_1)$) vanishes.

Nonlinear excitations in photonic honeycomb lattices

5 Dec
15:55

Edward Arévalo and Luis Morales Molina

Facultad de Física, Pontificia Universidad Católica de Chile, Santiago, Chile

The interplay between nonlinearity and the band structure of pristine honeycomb lattices is systematically explored. For that purpose, we develop a theory of collective excitations valid for the first Brillouin zone of this lattice. Closed-form expressions of two-dimensional excitations are derived for Bloch wavenumbers beyond the high-symmetry points of the Band structure. We show that the unbounded nature of 2D nonlinear excitations in honeycomb systems is a signature of the strong influence of the Dirac cones in other parts of the band structure.

Nonlinear Fokker-Planck Equations with Curl Drift Fields

5 Dec
16:20

R.S. Wedemann[1], A.R. Plastino[2], and C. Tsallis[3,4]

[1] Instituto de Matemática e Estatística, Universidade do Estado do Rio de Janeiro (UERJ)
[2] CeBio y Secretaría de Investigación, Universidad Nacional del Noroeste de la Província de Buenos Aires, (UNNOBA)
[3] Centro Brasileiro de Pesquisas Físicas (CBPF) and
National Institute of Science and Technology for Complex Systems (INCT-SC),
[4] Santa Fe Institute.

We have investigated nonlinear Fokker-Planck equations (NLFPE) endowed with curl drift forces, and determined the conditions under which these evolution equations admit stationary solutions. When these stationary solutions exist, we found that the NLFPE satisfy an H-theorem in terms of a free-energy-like quantity, involving the S_q entropy. A two dimensional model admitting analytical, time-dependent, q-Gaussian solutions is discussed in detail. This model describes a system of particles with short-range interactions, performing overdamped motion under drag effects, due to a rotating resisting medium. We discuss the relevance of the present developments to the study of complex systems in physics and other disciplines.

In neuroscience, we conjecture that NLFPE with curl drift fields may be relevant to modeling memory associativity, which is a key feature in the theoretical description of mental phenomena. Our previous work has focused on modeling this mechanism in traditional neural network models of memory, in which the symmetry of synaptic connections is a necessary condition for reaching stationary states. The assumption of symmetric weights seems however to be biologically unrealistic. Efforts to model stationary network states with asymmetric weights are mathematically complex and are usually applied to restricted situations. This has motivated us to explore the possibility of approaching the synaptic asymmetry problem, based on its analogies with some features of the aforementioned nonlinear Fokker-Planck formalism.

[1] R.S. Wedemann, A.R. Plastino, and C. Tsallis. Curl Forces and the Nonlinear Fokker-Planck Equation. arXiv:1609.00972 (2016).
[2] R.S. Wedemann, and A.R. Plastino. Asymmetries in Synaptic Connections and the Nonlinear Fokker-Planck Formalism. In: A.E.P. Villa et al. (Eds.), ICANN 2016, Part 1, Lecture Notes in Computer Science **9886**, 19–27 (2016).
[3] R.S. Wedemann, R. Donangelo, and L.A.V. Carvalho. Generalized Memory Associativity in a Network Model for the Neuroses. Chaos **19**, 015116-(1–11) (2009).

Climate Networks and Extreme Events

5 Dec
19:00
UAustral

Jürgen Kurths

Potsdam Institute for Climate Impact Research, Potsdam, Germany
Humboldt University, Berlin, Germany
Kings College, University of Aberdeen, Scotland

We analyse climate dynamics from a complex network approach. This leads to an inverse problem: Is there a backbone-like structure underlying the climate system? For this we propose a method to reconstruct and analyze a complex network from data generated by a spatio-temporal dynamical system. This approach enables us to uncover relations to global circulation patterns in oceans and atmosphere. We also evaluate different regional climate models from this aspect. This concept is also applied to Monsoon data; in particular, we develop a general framework to predict extreme events by combining a non-linear synchronization technique with complex networks. Applying this method, we uncover a new mechanism of extreme floods in the eastern central Andes which could be used for operational forecasts. Moreover, we analyze the Indian Summer Monsoon (ISM) and identify two regions of high importance. This leads to an improved prediction of the onset of the ISM.

[1] Runge, J. , J. Heitzig, V. Petoukhov, J. Kurths, Phys. Rev. Lett. 108, 258701 (2012).
[2] Boers, N., B. Bookhagen, N. Marwan, J. Kurths, and J. Marengo, Geophys. Res. Lett. 40, 4386 (2013).
[3] N. Boers, B. Bookhagen, H.M.J. Barbosa, N. Marwan, J. Kurths, and J.A. Marengo, Nature Communications 5, 5199 (2014).
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[7] V. Stolbova, E. Surovyatkina, B. Bookhagen, and J. Kurths, Geophys. Res. Lett. (2016).

Glaciological studies in Patagonia and the Antarctic ice sheet

6 Dec
09:00

Francisca Bown

CECS, Valdivia, Chile

Largest glaciated areas in the Southern Hemisphere are storaged in Patagonia and Antarctica, therefore they have been an object of study and exploration for centuries by the scientific community in Chile and abroad. In recent decades, calving glaciers of the Southern Patagonia Icefield have proven particularly sensitive to climate changes, amplifying their withdrawal through abnormally high-retreat and thinning rates. Antarctica is a fully ice-covered continent containing numerous subglacial lakes isolated from the surface, challenging Earth & Life Sciences research at present and future.

Forecasting Tsunamis?

6 Dec
09:35

Theo Geisel, H. Degueldre, R. Fleischmann, and J. Metzger

Max-Planck Institute for Dynamics and Self-Organization, Göttingen, Germany
Department of Physics, Georg August University Göttingen, Germany

Tsunamis are a threat to many countries and in particular to Chile with its extreme geographic aspect ratio. Being able to forecast the propagation of tsunamis as well as their impact on coastal areas therefore is a highly relevant goal and can save lives and property. I will discuss the feasibility of tsunami forecasts under the limitations that earthquakes are largely unpredictable and that tsunamis typically propagate at 200 – 900 km/h. This leaves a time span between minutes to some hours for useful tsunami predictions. We are asking in particular, what quantum chaos can tell us about the propagation of tsunamis and investigate the effect of random caustics due to fluctuations of the ocean depth. These can easily magnify wave amplitudes by an order of magnitude [1]. Our results are calling for more accurate measurements of the ocean depth.

[1] Degueldre, H, Metzger, J. J., Fleischmann, R., and Geisel, T., Nature Phys. 12 (2016) 259.

Exploding dissipative solitons

6 Dec
10:10

Orazio Descalzi[1], Carlos Cartes[1], Jaime Cisternas[1], and Helmut R. Brand[2]

[1] Complex Systems Group, Facultad de Ingeniería y Ciencias Aplicadas, Universidad de los Andes, Santiago, Chile
[2] University of Bayreuth, 95440 Bayreuth, Germany

We review our theoretical work on exploding dissipative solitons in one and two spatial dimensions. Explosions of solitons in a Kerr lens mode-locked Ti:sapphire laser were found experimentally more than ten years ago [1]. However, very recently, new evidence of exploding dissipative solitons has emerged from an experiment in a Yb-doped mode-locked fiber laser [2]. These pulses exhibit spatiotemporal chaos, thus, a feature of the experimentally observed explosions is that they are similar but not identical to each other. Although the real system is not continuous, this dynamical behavior was predicted theoretically in a continuous model, namely, the one-dimensional complex cubic-quintic Ginzburg-Landau equation (CQGLE) [3]. There these pulse solutions present an unstable time evolution but nevertheless they remain confined in space. Large-amplitude explosions might be considered as extreme events. Using this prototype equation, a transition from stationary pulses to exploding dissipative solitons (DSs) via pulses that oscillate with one and two frequencies, has been found [4]. This analogue of the Ruelle-Takens route for spatially localized solutions indicates the chaotic nature of explosions [5]. However for sufficiently large multiplicative noise the formation of stationary and temporally periodic dissipative solitons is suppressed. This result is characterized by a linear relation between the bifurcation parameter and the

noise amplitude required for suppression. For the regime associated with exploding dissipative solitons we find a reduction in the number of explosions for larger noise strength as well as a conversion to other types of dissipative solitons or to filling-in and eventually a collapse to the zero solution [6]. In two spatial dimensions we study the diffusive motion induced by symmetric and asymmetric explosions [7]. We report anomalous diffusion induced by intermittency between long sequences of symmetric and asymmetric explosions [8].

[1] S.T. Cundiff, J.M. Soto-Crespo, and N. Akhmediev, Phys. Rev. Lett. **88**, 073903 (2002)
[2] A.F.J. Runge, N.G.R. Broderick, and M. Erkintalo, Optica **2**, 36 (2015)
[3] J.M. Soto-Crespo, N. Akhmediev, and A. Ankiewicz, Phys. Rev. Lett. **85**, 2937 (2000)
[4] O. Descalzi and H.R. Brand, Phys. Rev. E **82**, 026203 (2010)
[5] O. Descalzi, C. Cartes, J. Cisternas, and H.R. Brand, Phys. Rev. E **83**, 056214 (2011)
[6] O. Descalzi, C. Cartes, and H.R. Brand, Phys. Rev. E **94**, 012219 (2016)
[7] C. Cartes, J. Cisternas, O. Descalzi, and H.R. Brand, Phys. Rev. Lett. **109**, 178303 (2012)
[8] J. Cisternas, O. Descalzi, T. Albers, and G. Radons, Phys. Rev. Lett. **116**, 203901 (2016)

Listening to a bird's dream

6 Dec
11:15

Gabriel Mindlin

Depatamento de Física, FCEyN, Universidad de Buenos Aires, Buenos Aires, Argentina.

Birdsong is an outstanding example of how a nonlinear peripheral device interacts with the nervous system in order to generate behavior. In the last years, we have been working on a low dimensional model of birdsong production that traduces physiological gestures (air sac and muscle activity) into song. We have found that during sleep, muscle activity at the syrinx displays song like activity, consistent with reports on neural activity that correlates with motor patterns registered during song production. Yet, neural activity patterns during sleep that do not correlate with motor patterns actually used during song production cannot be interpreted. Muscle activity, on the other hand, can be smoothly translated into song. With this strategy, we' ll show how to use a model of birdsong production to listen to a bird's dream.

Multiplicative Asset-Exchange Models: Properties and Applications

6 Dec
11:50

Cristian Moukarzel
CINVESTAV, Merida, Mexico

Recent advances in the field of Multiplicative (e.g. Yard-Sale) models of commercial exchange, both in and out of equilibrium, will be described. Conditions can be given under which the trade dynamics gives rise to condensation of wealth onto a few agents in the long run. The resulting time-dependent wealth distribution can be derived asymptotically by solving the Langevin equation for agent wealths under random multiplicative noise (modeling investment) and Yard-Sale trade (modeling commercial exchange). Comparison of our results against multi-period real-world data for the distribution of per-capita gross domestic products (gdp), suggests that the world-distribution of gdp can be adequately described by our model. Based on these observations, we furthermore argue that the time evolution of gdp in the last decades indicates that prevailing trade conditions appear to be systematically biased in favor of wealthier countries, thus leading to concentration of wealth in the long run. Our investment-exchange model can be extended by including a linear taxation-redistribution process, in which case an equilibrium state always exists, whose properties and relevance for the modeling of real-world data will be discussed as well.

Stochastic Processes & Block Matrices in Multilayer Networks

6 Dec
12:25

Regino Criado and Miguel Romance
Departamento de Matemática Aplicada, Universidad Rey Juan Carlos, Madrid, Spain; and
Centre for Biomedical Technology, Technical University of Madrid, Spain.

Many complex systems in the real world consist of components that cannot function independently, but interact among them through different channels of connectivity and dependencies. Several such systems have been studied through Complex Networks theory [1, 3, 5, 7, 8, 9].

Multilayer and multiplex networks [4, 6] explicitly incorporate multiple channels of connectivity in a system and constitute the natural mathematical setting for representing systems whose elements are interconnected through different kinds of connections (or levels); thus each level (channel, relationship, activity, category) is represented by a layer containing all the elements that have connections at that particular level. Notice that two elements may belong to two different layers if they are connected at more than one level (family level, or work level or friendship and vicinity levels etc.).

On the other hand, the ranking of nodes in multiplex networks is one of the most pressing and challenging tasks that research on complex networks is currently facing [10, 11]. When pairs of nodes can be connected through multiple links and in multiple layers, the ranking of nodes should necessarily reject the importance of nodes in one layer as well as their importance in other interdependent layers. To evaluate the importance of a node in a network and the corresponding ranking, the classic PageRank centrality draws on the idea

of a web surfer that visits different parts of the network at random. The random walker folows two strategies: the first one is jumping randomly to one of the walker's neighbors and the second one is jumping to a node selected uniformly at random. The importance of a node is a function of the frequency with which the random walker visits the node.

In this talk, a new view of the PageRank algorithm inspired by multiplex networks is presented. This new approach allows to introduce a new centrality measure for classic complex networks and a new proposal to extend the usual PageRank algorithm to multiplex networks. Some analytical relations between these new approaches and the classic PageRank centrality measure together its conceptual basis are also presented [12, 13]. Finally, some analytical relations between these new approaches and the classic PageRank centrality measure will be presented, and the new parameters presented will be illustrated by computing them on real underground networks.

[1] Albert, R., Barabási, A.L., Statistical mechanics of complex networks, Rev. Mod. Phys. 2002;74:47–97.
[2] Barabási, A.L., Albert, R., Emergence of scaling in random networks, Science 1999;286:509–512.
[3] Bar-Yam, Y., Dynamics of Complex Systems, Addison-Wesley; 1997.
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Bifurcation induced by the aspect ratio in a turbulent Von-Kármán swirling flow

6 Dec
14:00

Olivier Liot and Javier Burguete

Departamento de Física y Matemática Aplicada, Universidad de Navarra, Navarra, Spain

We evaluate the effect of two experimental parameters on the slow dynamics of a Von-Kármán swirling flow driven by two propellers in a closed cylinder. The first parameter is the inertia momentum of the propellers, and the second parameter is the aspect ratio, i.e. the distance between the propellers H divided by the diameter D. We use a cell with a fixed diameter D but where the distance between the propellers can be turned continuously and where the inertia from the propellers can also be changed using different gears. No change on the dynamics is observed when the momentum of inertia is modified. Some dramatic changes of the shear layer position are observed modifying the aspect ratio $\Gamma = H/D$. A bifurcation of the shear layer position appears. Whereas for low Γ the shear layer position has a smooth evolution when turning the asymmetry between the rotation frequency of the propellers, for high Γ the transition becomes abrupt and a symmetry breaking appears. Secondly we observe that the spontaneous reversals already observed in this experiment for $\Gamma = 1$ [de la Torre & Burguete PRL 99, 054101 (2007)] exist only in a strait window of aspect ratio. We show using an experimental study of the mean flow structure and a numerical approach based on a Langevin equation with coloured noise that the shear layer position seems to be decided by the mean flow structure whereas the reversals are linked to the spatial distribution of the turbulent fluctuations in the cell.

Synchronization and Complexity Control in Some Hyperchaotic Systems

6 Dec
14:00

Héctor L. Mancini[1], Gerard Vidal[2], Rabei Becheikh[3], Safya Belghith[3], and Javier Burguete[1]

[1] Universidad de Navarra, Departamento de Física y Matemática Aplicada. Pamplona, Spain,
[2] Enigmedia, Spain,
[3] École Nationale d'Ingénieurs de Tunis ENIT, RISK laboratory, Université de Tunis El Manar, Tunisia

It is well known that in thermo-convective systems increasing an external control parameter as temperature or heath flow, secondary and higher order bifurcations brings to pre-turbulent states with space-time dependent patterns, before developed turbulence destroy these structures. In addition to their intrinsic interest in fluid dynamics, these kinds of experiments have been frequently used to check nonlinear dynamic theories on pattern formation with different scales, symmetries and boundaries. In this work we present a brief review and new results about our numerical experiments with hiperchaotic mathematical models, addressed to analyze how complex pre-turbulent (space-time chaotic) dynamical states could be synchronized or controlled considering their symmetries.

Alternating superlattice textures in driven nanomagnets

6 Dec
14:00

Ana M. Cabanas[1], Alejandro O. León[2], David Laroze[1], and Marcel Clerc[2]

[1] Instituto de Alta Investigación, Universidad de Tarapacá, Casilla 7D, Arica, Chile
[2] Departamento de Física, Facultad de Ciencias Físicas y Matemáticas, Universidad de Chile, Casilla 487-3, Santiago, Chile

Nanomagnets driven with uniform electric currents exhibit a wide variety of spatial textures. In the present work, we investigate alternating superlattice states in nanomagnets, which are spatially periodic textures composed by several spatial modes that oscillate in time. The magnetic system is described in the continuum approach by the Landau-Lifshitz-Gilbert-Slonczewski equation [1], and direct numerical simulations of this model allow us to characterize the alternating patterns. As a result of this temporal oscillation, textures alternate between different shapes. In particular, we focus on two types of textures, namely a superhexagon and a square-like pattern, which are composed by six and two dominant Fourier modes, respectively [2]. Based on an appropriate modal decomposition, we reveal that the mechanism that originates the alternating superhexagon is a homoclinic bifurcation. In addition, we show that the oscillatory square-like texture emerges through a supercritical Andronov-Hopf bifurcation.

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Periodic exploding dissipative solitons

6 Dec
14:00

Carlos Cartes, and Orazio Descalzi

Complex Systems Group, Facultad de Ingeniería y Ciencias Aplicadas, Universidad de los Andes, Santiago, Chile

This work will show the existence of periodic exploding dissipative solitons. These nonchaotic explosive objects appear when higher-order nonlinear and dispersive effects are added to the complex cubic-quintic Ginzburg-Landau equation modeling fiber soliton lasers. This highly non trivial phenomenon is the result of period-halving bifurcations leading to order (periodic explosions), followed by period-doubling bifurcations leading to chaos (chaotic explosions).

Inverse percolation by removing straight rigid rods from square lattices

6 Dec
14:00

L. S. Ramírez, Paulo M. Centres, and A. J. Ramírez-Pastor

Departamento de Física, Instituto de Física Aplicada, Universidad Nacional de San Luis-CONICET, Ejército de Los Andes 950, D5700HHW San Luis, Argentina

Numerical simulations and finite-size scaling analysis have been carried out to study the problem of inverse percolation by removing straight rigid rods from square lattices [L.S. Ramirez et al. *J. Stat. Mech.* P09003 (2015)]. The process starts with an initial configuration, where all lattice sites are occupied and, obviously, the opposite sides of the lattice are connected by nearest-neighbor occupied sites. Then, the system is diluted by randomly removing straight rigid rods of length k (k-mers) from the surface. The central idea of this paper is based on finding the maximum concentration of occupied sites (minimum concentration of holes) for which connectivity disappears. This particular value of concentration is called the inverse percolation threshold, and determines a well-defined geometrical phase transition in the system. The results, obtained for k ranging from 2 to 256, showed a non-monotonic size k dependence for the critical concentration, which rapidly decreases for small particle sizes ($1 \leq k \leq 3$). Then, it grows for $k = 4$, 5 and 6, goes through a maximum at $k = 7$, and finally decreases again and asymptotically converges towards a definite value for large values of k. Percolating and non-percolating phases extend to infinity in the space of the parameter k and, consequently, the model presents percolation transition in all ranges of said value. This finding contrasts with the results obtained in literature for a complementary problem, where straight rigid k-mers are randomly and irreversibly deposited on a square lattice, and the percolation transition only exists for values of k ranging between 1 and approximately 1.2×10^4. The breaking of particle-hole symmetry, a distinctive characteristic of the k-mers statistics, is the source of this asymmetric behavior. Finally, the accurate determination of critical exponents reveals that the model belongs to the same universality class as random percolation regardless of the value of k considered.

Characterization of nonlinear hypersonic flow in atmospheric sounding using permutation entropy

6 Dec
14:00

Edgardo Comas and Walter Legnani

Institute of Scientific and Technical Research for Defense; Zufriategui 4380 Villa Martelli; Buenos Aires, Argentina

This work is based on the plasma flow in hypersonic flight from the measurements made in a vector of atmospheric sounding. With this framework we have analyzed the data obtained from the flight of SONDA vector for the high atmospheric study (GRADICOM II Project), which was launched on 11 July 2011 by the Institute of Scientific and Technical Research for Defense, and it reached an apogee of 92 km approximately and a maximum speed of 6.56 MACH. During the vector flight the formation of plasma appears immediately after entering hypersonic flight. The acceleration data was acquired using three axes Inertial

Measurement Unit with a sampling time of two milliseconds. The chaotic behavior in the accelerations on the vector body was studied using traditional tools like Liapunov exponents, complemented with the compute of entropy and permutation entropy (PE). To compute the PE we windowed the data using a segmentation in sections from 2000 to 12000 samples each one to provide a wide point of view of the impact of the window size in the results. The use of information tools like as entropy and specially PE has contributed to improve the analysis of the results and brought a completely description of each stage of the flight. In this sense the vector flight was composed by two propulsion stages, each of one could was very well identified applying PE. The data recorded ended when the vector enters in a blackout caused when the plasma covers of the whole body of the vehicle. But exist a very interesting regime, after the second propulsion stage ends and the blackout appears, in which the conical movement of the vector's nose acquires a chaotic behavior, and this can be identified through two ways: one given by the reconstruction of the attractor, and other, very clear differentiated from the previous regimes, by the PE. This work constitutes another example of the success of the PE when is applied to real life data of considerable length. The advantages of PE use can be summarized as: was implemented using a fast algorithm, so it can be processed in practical real time to correct flight parameters, is independent of the attractor reconstruction, in this sense is and independent of the geometric measures of the chaotic behavior, have a temporal resolution higher than other nonlinear tools to identify each state of the flight and contributes to classify each one very clear.

The recorded signals do not require any preprocessing technique to adapt the data to be suitable to be processed using PE. Additionally, permutation entropy constitutes an interesting choice in signal processing due do not requires a fine tuning of parameters, thus providing an efficient implementation in many circumstances.

By other way, using classical tools to reconstruct the characteristic attractor of the flight, in place to record the three axes during the vector flight we arrive to the conclusion that one precise axes measure is enough to study the main features of the dynamics, so it can be applied in lowering the instrumentation aboard.

The main results of this work are a novel insight in the knowledge of the vector sounding of the high atmosphere. The main results existing in the literature refers to the reentry of vehicles to the atmosphere, but the deep study of many aspects of the vector flight from the take off and reaching the blackout will be to do.

Reduced basis method applied to an instability problem from a Rayleigh-Bénard convection

6 Dec
14:00

Francisco Pla and Henar Herrero

Departamento de Matemáticas, Facultad de Ciencias y Tecnologías Químicas, Universidad de Castilla-La Mancha, 13071 Ciudad Real, Spain

The reduced basis approximation is a suitable method to find numerical solutions of parameter-dependent problems $\mathcal{P}(\phi(\mu), \mu) = 0$ with parameter μ in cases of many queries. This method consists of approximating the solution $\phi(\mu)$ of $\mathcal{P}(\phi(\mu), \mu) = 0$ by a linear combination of *appropriate* preliminary computed solutions $\phi(\mu_i)$ with $i = 1, 2, \ldots, N$ such that μ_i are parameters chosen by an iterative procedure using the *Kolmogorov* n*-width* measures [2, 4].

In [1], the reduced basis method is applied to a two dimensional incompressible Navier-Stokes equations with constant viscosity and the Boussinesq approximation coupled with a heat equation that depends on the Rayleigh number, $\mathcal{P}(\phi(R), R) = 0$.

Rayleigh-Bénard convection problem displays multiple steady solutions and bifurcations by varying the Rayleigh number, therefore the eigenvalue problem of the corresponding linear stability analysis has to be implemented. A linear stability analysis of these solutions is performed in [3] by spectral collocation method.

In this work the reduced basis method is applied to solve eigenvalue problems of the linear stability analysis of stationary solutions from a two dimensional Rayleigh-Bénard convection problem. It is considered the aspect ratio $\Gamma = 3.495$ and R varies in [1,000; 2,000] where different stable and unstable bifurcartion branches appear [1, 3]. The reduced basis considered belong to the eigenfunction spaces coming from the eigenvalue problems for different types of solutions in the bifurcation diagram. The eigenvalues and eigenfunctions are easily calculated and the bifurcation points are exactly captured. The resulting matrices are small and this allows a drastic reduction of the computational cost on the eigenvalue problems.

The problem is numerically solved by the Galerkin variational formulation using the Legendre Gauss-Lobatto quadrature formulas together with the reduced basis $\{\Psi(R_i), i = 1, 2, \ldots, N\}$ such that $\Psi(R) \sim \sum_{i=1}^{N} \lambda_i \Psi(R_i)$.

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Stochastic resonance in simple electrical circuits driven by quadratic Gaussian noise

6 Dec
14:00

H. Calisto[1] and Fernando R. Humire[2]

[1] Sistema de Bibliotecas Universidad de Tarapacá, Arica, Chile,
[2] Instituto de Física, Pontificia Universidad Católica de Valparaíso, Chile.

In this article we report exact analytical and numerical evidences of the occurrence of the stochastic resonance phenomenon in simple electrical circuits driven by a quadratic Gaussian colored noise and by a Gaussian white noise. As an example we have used an RL configuration. However, it is clear that the phenomenon occurs in any other configuration governed by the same type of evolution equation. The main result is that the phenomenon occurs with a quadratic colored noise. When noise enters only linearly we have verified that the stochastic resonance occurs both with colored noise and white noise. The robustness of our results were verified by calculating the variance as a function of time in each case. We believe that the results obtained could be observed in a laboratory experiment using some kind of digital resistance. The white noise limit with quadratic noise was excluded.

Statistical analysis of bubble emissions in liquid-saturated sands

6 Dec
14:00

Gladys Jara, Felipe Olivares and Germán Varas

Instituto de Física, Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile

The aim of this work is to experimentally study the dynamics of gas passing through liquid-saturated sands. To do so, a controlled air flow is injected at the base of a 2D granular bed immersed in water and the pressure δP is measured close to the injection point. Typically, the pressure signal for this type of system presents an intermittence between two characteristic regimes. For low flow-rate, successive bubbles cross the medium (bubbling regime) and for high flow-rate the channel's walls are stable and a continuous gas flow escapes from the granular bed (open channel regime). An intermittence between these two regimes is observed for intermediate flow-rates. We use Detrended Fluctuation Analysis (DFA) to estimate the Hurst exponent in order to quantify temporal correlations in the pressure signal. This characterization allows us to understand the role of the grains height h_g and the flow-rate Q in the history that bubbles leave in the system and quantify the memory of the air channel.

Phase diagram of site-bond percolation

6 Dec
14:00

M. I. González[1], P. Centres[1], A. J. Ramírez-Pastor[1] and Walter Lebrecht[2]

[1] Departamento de Física, INFAP, Universidad Nacional de San Luis, CONICET, Ejército de Los Andes 950, D5700HHW, San Luis Argentina

[2] Departamento de Ciencias Físicas, Universidad de La Frontera, Casilla 54-D, Temuco, Chile.

The site-percolation problem on square, triangular and simple cubic lattices has been studied by means of numerical simulation and analytical calculations based on exact counting of configurations on finite cells [1-5]. Motivated by considerations of cluster connectivity, two distinct schemes (denoted as $S \bigcap B$ and $S \bigcup B$) have been analyzed. In $S \bigcap B (S \bigcup B)$, two points are said to be connected if a sequence of occupied sites AND (OR) bonds joins them.

In order to obtain the percolation functions corresponding to $S \bigcap B$ and $S \bigcup B$ site-bond percolation, operations AND (Series) and OR (Parallel) proposed by Tsallis [6] were considered. The percolation threshold was obtained by numerical simulation using the Hoshen-Kopelman algorithm. Then, the percolation thresholds were obtained by analytical calculations based on exact counting on all possible configurations that are presents on a finite cell. A good qualitative agreement between numerical and theoretical data was found, especially in the case of square lattices. However, appreciable differences were observed for $S \bigcap B$ criterion in the case of triangular and simple cubic lattices.

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Optical transmission of information using orbital-angular-momentum states: misconceptions and challenges

6 Dec
14:35

Jaime A. Anguita

Universidad de los Andes, Santiago, Chile
CEFOP, Concepción, Chile

Optical transmission of information may improve in bandwidth and robustness with the use of specialty beams carrying orbital angular momentum (OAM). OAM-carrying laser modes rotate around their propagation axis and feature a dark central spot due to their phase dislocation. A collection of modes with the same amplitude profile but distinct integer OAM states form an orthogonal set of functions. Consequently, an optical system can superimpose and afterwards separate constituent modes without interference. Such property allows the use of OAM modes for multiplexing communication channels and/or for multi-dimensional modulation of the carriers. Some have stated that OAM provides infinite capacity due to the unbound number of states that can be used. We explain what limits this capacity and how this compares with other orthogonal basis for information transmission. In the presence of turbulence, where spatial variations in the refractive index of the air modify the phase structure of the vortex, single-state OAM signals are spread over several states, thus, impairing the detection and increasing symbol errors. Nevertheless, OAM-based communication is still feasible in the presence of turbulence. The communication of simultaneous OAM channels has been studied considering the effects of realistic OAM crosstalk for various turbulence strength conditions and improved transmissions have been demonstrated in controlled environments with simulated turbulence and adaptive optics. A review of the channel fluctuations experienced by OAM signals and the random mode interference both from numerical simulations and recent outdoor experiments will be given at this presentation.

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In situ monitoring of dislocation proliferation during plastic deformation using ultrasound

6 Dec
15:30
Salón
Provincial

Vicente Salinas[1], Fernando Lund[1], Nicolás Mujica[1], Rodrigo Espinoza-González[1], and Claudio Aguilar[2]

[1] Universidad de Chile

[2] Universidad Técnica Federico Santa María

Ultrasound has long been used as a non-destructive tool to test for the brittle fracture of materials. Could it be used as a similar tool to test for ductile failure? We report results of local measurements of the speed of shear waves in aluminum under standard testing conditions at two different probe locations and continuously as a function of applied load. The result, as expected, is independent of strain in the elastic regime but there is a clear change, consistent with a proliferation of dislocations, as soon as the yield strength is reached. A model that blames the change in wave speed on the interaction of elastic waves with oscillating dislocation segments is used to quantitatively relate the change in wave velocity with dislocation density Λ and segment length L, thus obtaining a continuous relation between dislocation density and externally applied stress. Samples have been taken off the probe after low, intermediate, and high loading and their dislocation density has been measured using standard X-ray diffraction and Transmission Electron Microscopy techniques. The results agree well with the acoustic measurements. This indicates that monitoring the speed of shear waves could become a useful diagnostic of dislocation density for metallic pieces in service as well as a useful tool to test models of plastic behavior.

Gravity waves influenced by vortices

6 Dec
15:55
Salón
Provincial

Pablo Gutiérrez, Alfredo García-Cid, and Claudio Falcón

Departamento de Física, FCFM, Universidad de Chile

When a container with liquid moves horizontally, the liquid may attain very high amplitudes, even producing spilling or destabilization of the container. One deals with this problem, rather unconsciously, when walking with a cup of coffee [Mayer & Krechetnikov, PRE 2012]. Such an anecdotal problem, however, has relevant implications in the transport of large amounts of fuel. Consequently, it has deserved intense investigations [Ibrahim, 2005; Herczynski & Weidman, JFM 2012].

To avoid violent increases in the maximal heigh of the liquid, it is usually proposed to use particular container geometries [Ibrahim, 2005]. Here we explore how fluid motion itself may provide an alternative control mechanism. To go in this direction,we study the gravity waves that appear as low-frequency resonances on the free surface of a water volume, when its container is subjected to a horizontal periodic forcing. Specifically, we focus on how vortical fluid motion attenuates these resonances.

The attenuation of gravity waves by vortical fluid motion has been intensively considered in physics and oceanography. We review some theoretical and experimental works, with particular attention to recent experimental results [Gutiérrez & Aumaître, PoF 2016]. Then

we present our experiment: we induce resonances in the free surface of water by vibrating the container horizontally while four DC motors with impellers produce vortices in the bulk. Our measurements of the surface deformation show that the generated vortices gradually attenuate the resonances. On the basis of a simple mechanical model, we explore the connections between vorticity and an effective viscosity dissipating wave energy. Finally we place this problem in the more general context of interaction between waves and vortices, to give other perspectives of our study.

Shaping magnetic hysteresis

6 Dec
16:20
Salón
Provincial

Paula Mellado, David Aguayo, and Andrés Concha
School of Engineering and Applied Sciences,
Adolfo Ibáñez University, Santiago, Chile

We introduce a minimal experimental setup where magnetization dynamics realizes in several fashions. It consists of $U(1)$ ferromagnetic magnets forming a chain along the $\hat{x}$ direction. The shape of the magnetization reversal curve depends on the symmetry of the interacting magnets and on the direction of the magnetic field respect to the chain direction: chains made out of $x-y$ magnets display two hysteresis loops when the field is applied perpendicular to the chains axis. If the field is parallel to the chain direction, the outcome is a squared loop. When the field is perpendicular to the chain axis and the magnets rotate in the $y-z$ plane, the process is reversible. $M(\mathbf{B})$ is reproduced by a dynamics consisting of Coulomb interactions among magnetic charges at the ends of the magnets, Zeeman coupling with the external field and viscous dissipation due to frictional rotation. Coulomb coupling plus the rotational symmetries of the magnets determine the metastable states of the system and its equilibrium configurations at zero field. Once it breaks the symmetry of the chain, the orientation of $\mathbf{B}$ respect to it defines the mechanism of reversal fixing the shape of the magnetization curve. The model allows easy computation of the system proper frequencies which sets a cutoff for the field sweeping rate aimed to perceive full resolution of the dynamical process.

Ising-based social interactions

6 Dec
16:45
Salón
Provincial

Sergio Rica
Facultad de Ingeniería y Ciencias, Universidad Adolfo Ibáñez, Chile

In this talk I will discuss a few Ising-like mechanisms for self-organized social structures. First, I will discuss the case of binary decisions as political elections and social segregation. Next, I will review a general social interaction model proposed by James Sakoda in 1971 for social behavior which appears to be in the universality class of the Potts model. The present work has been benefited with the close collaboration with R. Truffello, F. Mora, P. Medina and E. Goles, and the financial support by Núcleo Milenio Modelos de Crisis NS130017 CONICYT (Chile).

Radio Spectrum Scarcity Problems? Try Quantum Minority Game!

6 Dec 15:30 Salón Los Conquistadores

Miguel Arizmendi

Departamento de Física, Facultad de Ingeniería, Universidad de Mar del Plata, Mar del Plata, Argentina

The usual problem of radio spectrum is its scarcity. This presents a competitive scenario among users, making it suitable for game theory treatment. In this context, we propose a model to manage spectrum fairly and effectively, based on a multiple-users multiple-choice quantum minority game. By taking advantage of quantum entanglement and quantum interference, it is possible to reduce the probability of collision problems commonly associated with classic algorithms. Collision avoidance is an essential property for classic and quantum communications systems. In our model, two different scenarios are considered, to meet the requirements of different user strategies. The first considers sensor networks where the rational use of energy is a cornerstone; the second focuses on installations where the quality of service of the entire network is a priority.

Model selection: Using information measures from ordinal symbolic analysis to select model sub-grid scale parameterizations

6 Dec 15:55 Salón Los Conquistadores

Manuel Pulido[1] and Osvaldo A. Rosso[2,3]

[1] Departamento de Física, FaCENA, Universidad Nacional del Nordeste (UNNE), Corrientes, Argentina.

[2] Instituto de Física, Universidade Federal de Alagoas (UFAL), Maceió, Alagoas, Brazil.

[3] Instituto Tecnológico de Buenos Aires (ITBA), Ciudad Autónoma de Buenos Aires, Argentina.

The use of information measures as a means of model selection is explored to diagnose model parameterizations and to develop them. Although the resolved dynamical equations of atmospheric or oceanic global numerical models are well established, the development and evaluation of parameterizations that represent subgrid-scale effects pose a big challenge. For climate studies, the parameters or parameterizations are usually selected according to a root mean square error criterion, that measures the differences between the model state evolution and observations along the trajectory. However, systematic model errors pervade the root mean square error measures particularly for parameterization evaluation where we expect different responses for different points in the state space. To overcome these difficulties, here we evaluate ordinal information theory quantifiers (Shannon entropy, statistical complexity) as measures of the model dynamics. This ordinal analysis is conducted using the Bandt-Pompe symbolic data reduction in the signals. It distinguishes different dynamical behaviors and discriminate clearly chaotic from stochastic signals. We examine the proposed ordinal information measures in the two-scale Lorenz'96 system. By comparing the two-scale Lorenz'96 system signals with a one-scale Lorenz'96 system with deterministic and stochastic parameterizations, we show that information measures are able to select the correct model and to distinguish the parameterizations including the degree of stochasticity that result in the closest model dynamics to the two-scale Lorenz'96 system.

Cardiac ischemic procedures analyzed using complexity tools

6 Dec
16:20
Salón Los
Conquista-
dores

Osvaldo A. Rosso[1,2], Walter E. Legnani[3,4], Leandro J. Cymberknop[3,4], and Ricardo L. Armentano[3,4]

[1] Instituto Tecnológico de Buenos Aires (ITBA), Ciudad Autónoma de Buenos Aires, Argentina
[2] Instituto de Física, Universida de Federal de Alagoas (UFAL) Maceió, Brasil
[3] Signals and Image Processing Center (CPSI), Universidad Tecnológica Nacional, Buenos Aires, Argentina
[4] Facultad de Ingeniería y Ciencias Exactas y Naturales, Universidad Favaloro, Buenos Aires, Argentina

Several studies can be found in the literature where the chaotic behavior of heart mechanics is evaluated. Usually, the techniques applied to the study of this important organ for living beings are based on the analysis of the electrical signals (by means of electrocardiography) that are recorded under different physiopathological conditions. As a result, the development of tools capable to identify ischemic conditions in real time constitutes the corn stone of advanced preventive cardiovascular medicine. The early detection of an ischemic process could contribute to extend the patient life, and improve its quality thus reducing the emergency medicine costs and associated mortality to this type of disease. The main goal of this work was to analyze the capability of complexity measures like permutation entropy (PE) and zero crossing rate (ZCR) coefficient in order to detect changes in the behavior of cardiovascular dynamics, under different physiological conditions (health and disease). The left ventricular dynamics was studied using two types of sensors. Firstly the left ventricular pressure (LVP) was measured by means of a solid state pressure transducer, introduced through a stab wound near the apex. Its sensing surface lies in direct contact with the blood flow and it has been designed to remain inside the organism for considerable time periods. The calibration process represents the main disadvantage together with thermal instability and fragility. Secondly, ventricular thickness (VWT) was assessed through the implantation of ultrasonic microcrystals (5 MHz) in the anterior (AVWT) and posterior (PVWT) ventricular walls. The implementation of the invasive experimental protocols was performed in vivo in animals (five mongrel dogs). All procedures were in accordance with the Guide for the Care and Use of Laboratory Animals published by the United States National Research Council (National Academy Press, Washington, DC, 1996). An ischemic maneuver was induced by clamping a silicone tube interposed between the subclavian and coronary arteries, affecting by this way the corresponding perfusion of the posterior ventricular wall. LVP and VWT (both anterior and posterior) were digitized during 15 seconds of occlusion, and then the clamp was opened to allow for reperfusion. The development of myocardial ischemia was characterized by means of classical hemodynamic measures, such as absolute positive and negative peaks of the first-order time derivative of LVP. The signals were acquired at a sampling frequency of 4000 Hz, during timeslots ranging from 60 to 105 seconds. Obtained data was then windowed in segments between 2000 and 12000 samples, in order to analyze the effect of the window size in PE algorithms. The results showed the ability of PE to detect the beginning of the ischemic process with a high accurate time resolution and low computational cost, without requiring the prior calibration of the signals (relative

changes between samples were only needed). It is noteworthy that PE was applied to real biological data, in which the order of the permutation has proven to be less than the estimated theoretically for series of synthetic data. This condition reinforces the fact that the calculation time is reduced, since to calculate the number of permutations of the data do not requires an inordinate amount of operations. As a result, the considerations regarding the application of this kind of analysis were evaluated in terms of an important, modern, and efficient complement to traditional signal analysis. In this sense, PE was complemented with the ZCR coefficient computation, which constituted an important tracer of the beginning and finishing points of the ischemic process. The application of information theory concepts to the signal processing field has become a recent international trend, opening a wide range of possibilities that could contribute to a deeper understanding of the hidden patterns in biological datasets. Moreover, this approach provides an appropriate way to obtain a description of the systems responsible of generating these kinds of signals.

Parameter Estimation Assessment by Information Content in Speckled Imagery

7 Dec
09:00

Magdalena Lucini[1], Juliana Gambini[1], and Alejandro C. Frery[3]

[1] Facultad de Ciencias Exactas, Naturales y Agrimensura, Universidad Nacional del Nordeste, Av. Libertad 5460, 3400 Corrientes, Argentina,

[2] Instituto Tecnológico de Buenos Aires, Lavardén 389, C1437FBG Buenos Aires, Argentina and Depto. de Ingeniería en Computación, Universidad Nacional de Tres de Febrero, Pcia. de Buenos Aires, Argentina,

[3] LaCCAN, Universidade Federal de Alagoas, Av. Lourival Melo Mota, s/n, 57072-900 Maceió – AL, Brazil

In this work we analyze a SAR (Synthetic Aperture Radar) image feature extraction method based on the estimation of the parameters of a statistical model largely used for this kind of data. The statistical model used is the $\mathcal{G}_I^0$ distribution, which with very few parameters is able to characterize a large number of targets in monopolarized SAR imagery, deserving the denomination of "Universal Model". One of these parameters, denoted α, is instrinsecaly related to the roughness or texture of the backscatter, being this fact one of the reasons why its estimation is of paramount importance and receives a great deal of attention in the cientific community. We here analyze the results of extracting this feature using several methods and algorithms for parameter estimation, including Maximum Likelihood, methods based on fractional moments , log-cumulants and a procedure based on asymmetric kernels and stochastic distances, as a previous step in SAR image classification. The quality of these estimates is assessed by the information content they convey. Maps generated by different estimators of α are used as the input for classification methods to discriminate land cover types and their performances are addressed in terms of the accuracy of the classification. The methodology here presented can also be applied to any image generated by coherent illumination, as is the case of ultrasound, laser and sonar images which can also be modeled by the $\mathcal{G}_I^0$ distribution.

Noise Parameter Estimation in Chaotic Nonlinear Dynamical Systems using Expectation Maximization Algorithm

7 Dec
09:00

Manuel Pulido[1], Pierre Tandeo[2], and Magdalena Lucini[1]

[1] Facultad de Ciencias Exactas, Naturales y Agrimensura, Universidad Nacional del Nordeste, Av. Libertad 5460, 3400 Corrientes, Argentina,
[2] Institut Minex-Telecom, Lab-STICC, Brest, France

The Expectation-Maximization algorithm (EM) is a widely used methodology to maximize the likelihood function in a broad spectrum of applications. One of the big advantages of the EM algorithm is that the implementation is rather straigthforward. Recently the EM algorithm was applied to a highly nonlinear observation operator, specifically an orographic subgrid-scale parameterization (which is present in several state-of-the-art numerical weather forecast models inclucing the ECMWF forecast model) and showed to be able to estimate the true subgrid-scale parameters with good accuracy while standard ensemble Kalman filter techniques failed.

In this work, we apply the EM algorithm to estimate stochastic physical and statistical parameters in chaotic nonlinear dynamical systems. The EM algorithm is used in conjunction with an ensemble Kalman filter (EnKF) and smoother, the last are used to obtain the intermidiate function conditioned to the observations and unknown parameters. A Newton-Raphson algorithm that maximizes the observation likelihood function is also implemented for comparison with the EM algorithm. The evaluation of the observation likelihood function also requires a Kalman filter and smoother. To that end, we implement an algorithm based on the ensemble-based Kalman filter which does not require the adjoint model for its application in nonlinear dynamical systems. The approach here proposed is evaluated in the one and two-scale Lorenz 96 systems.

The EnKF-EM algorithm is able to estimate both the dynamical noise and measurement noise with a good degree of accuracy. These approaches are shown to be useful for stochastic parameterization development and setting.

Hypothesis Testing for Texture Discrimination using the Geodesic Distance in SAR imagery under the $\mathcal{G}_I^0$ Model

7 Dec
09:00

José Naranjo-Torres[1], Juliana Gambini[2], Magdalena Lucini[3], and Alejandro C. Frery[4]

[1] Coordinación de Física, Instituto Universitario de Tecnología de Maracaibo, Urb. La Floresta Av. 85, Edif. IUTM, Maracaibo, Venezuela
[2] Instituto Tecnológico de Buenos Aires, Lavardén 389, C1437FBG Buenos Aires, Argentina and Depto. de Ingeniería en Computación, Universidad Nacional de Tres de Febrero, Pcia. de Buenos Aires, Argentina
[3] Facultad de Ciencias Exactas, Naturales y Agrimensura, Universidad Nacional del Nordeste, Av. Libertad 5460, 3400 Corrientes, Argentina
[4] LaCCAN, Universidade Federal de Alagoas, Av. Lourival Melo Mota, s/n, 57072-900 Maceió – AL, Brazil

In this work we analyze a SAR (Synthetic Aperture Radar) region discrimination method based on the Geodesic Distance (GD) and the estimation of the parameters of a statistical model largely used for this kind of data. The statistical model used is the $\mathcal{G}_I^0$ distribution which is indexed by three parameters: the number of looks (L), a scale parameter (γ), and a parameter (α) related to the roughness or texture of the backscatter. This fact is one of the reasons why the estimation of α receives a great deal of attention in the literature. This paper presents a new method to measure the separability between regions in SAR imagery using the GD (presented by Rao), under the $\mathcal{G}_I^0$ distribution. In order to asses the performance of the texture discrimination method, a hypothesis test is used. We derived closed form for the GD between models that describe several practical situations, assuming the number of looks known, for same and different texture and for same and different scale. The parameters, in each case, are estimated using the Maximum Likelihood method because we are specially interested in its asymptotic properties.

Neural coding and information processing

7 Dec
09:00

Lisandro Montangie and Fernando Montani
IFLYSIB, CONICET & Universidad Nacional de La Plata, Calle 59-789, 1900 La Plata, Argentina

Synchronization across spikes in neuronal populations has been linked to information transmission and sensory perception in the brain. That is, the spiking activity of cortical neurons may not be independent and several studies have explored the importance of this correlated activity. We investigate synchronized activity generated in groups of neurons of different population sizes by means of an information theory approach, and by using a computational model accounting for correlation structures of different orders in the neuronal inputs to that population. The synchronization patterns result fundamental for information coding in the brain where different areas may be coupled asymmetrically and it becomes a relevant issue for understanding how sensory perception is processed in the cerebral cortex.

Causal information to characterize the dynamics of EEG during motor type activity

7 Dec
09:00

Roman Baravalle[1], Osvaldo A. Rosso[2], and Fernando Montani[1]
[1] IFLYSIB, CONICET & Universidad Nacional de La Plata, Calle 59-789, 1900 La Plata, Argentina,
[2] Instituto Tecnológico Buenos Aires (ITBA), Av. Eduardo Madero 399, C1106ACD Ciudad Autónoma de Buenos Aires, Argentina.

Electroencephalograms (EEG) reflect the electrical activity of the brain, which can be considered ruled by a chaotic nonlinear dynamics. In this paper we consider the human EEG recordings during different motor type activities and when imagining that they perform this activity. We characterize the different regions of the cortex according to different motor and imaginative activities by frequency bands, and using the causal plane entropy-complexity

$H \times C$, information entropy versus Fisher $F \times H$ and the plane complexity-Fisher $C \times F$. This allows us to characterize the dynamics of neuronal activity to the motor and imaginative responses of such activities.

Characterization of neuronal dynamics using a non-Gaussian noise

7 Dec 09:00

Roman Baravalle[1], Osvaldo A. Rosso[2], and Fernando Montani[1]

[1] IFLYSIB, CONICET & Universidad Nacional de La Plata, Calle 59-789, 1900 La Plata, Argentina,

[2] Instituto Tecnológico Buenos Aires (ITBA), Av Eduardo Madero 399, C1106ACD Ciudad Autónoma de Buenos Aires, Argentina.

The study of the dynamics of a neuron given the current currents and the possible influence of emphatic coupling of the network has been a major issue for a long time in computational neuroscience. In our paper we propose a possible solution of the master equation of a neuron. We use a method of analysis based on comprehensive technical way to calculate the probability distribution of the onset potential considering a background noise and possible contributions of the surrounding activity. We consider a non-Gaussian noise as a possible source of correlated neural activity and estimate the complexity, entropy and Fisher information system characterizing the dynamics of the system.

Entropy harvest from isotropic optical turbulence

7 Dec 09:00

Felipe Olivares, Luciano Zunino, Damián Gulich, Dario Pérez, and Osvaldo A. Rosso

Instituto de Física. Pontificia Universidad Católica de Valparaíso (PUCV) Chile
Centro de Investigaciones Ópticas (CONICET La Plata - CIC) Argentina
Instituto de Física de Líquidos y Sistemas Biológicos (CONICET - UNLP) Argentina
Instituto de Física. Universidade Federal de Alagoas (UFAL) Brazil

We have experimentally quantified the entropy of isotropic optical turbulence at the laboratory. The issue here is the characterization of the long-range correlations in the wandering of a thin Gaussian laser beam over a screen after propagating through a turbulent medium [1]. To fulfill this goal, a laboratory-controlled experiment was conducted in which coordinate fluctuations of the laser beam were recorded at a sufficiently high sampling rate for a wide range of turbulent conditions by using a device called *turbulator* [2]. Horizontal and vertical displacements of the laser beam centroid were subsequently analyzed by implementing the symbolic technique based on ordinal patterns to estimate the well-known permutation entropy [3]. We show that entropy estimation at different time scales characterizes an interplay between different dynamical behaviors. More specifically, crossovers between different scaling regimes are observed. A transition from an extremely persistent behavior (due to oversampling) contaminated with electronic noise to long-range correlations (characterized by a Hurst exponent $H \sim 5/6$), as sampling rate decreases is observed for all turbulence strengths. Besides we are able to quantify the amount of electronic noise as a function of

the turbulence strength. These experimental observations are in very good agreement with numerical simulations of a noisy fractional Brownian motions with a well-defined crossover between different scaling regimes. Finally, we contrast our results with those obtained by using detrendred fluctuation analysis [1].

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Spin valve oscillator under a quasiperiodic current

7 Dec
09:00

Laura M. Pérez, A. M. Cabanas, and D. Laroze
Instituto de Alta Investigación, Universidad de Tarapacá, Casilla 7D, Arica, Chile

The current-driven magnetization dynamics in spin torque oscillators is investigated because of its high potential for high-frequency applications. This system consists on a pinned layer with a fixed magnetization and a single-domain free layer, such that it is governed by the Landau-Lifshitz- Gilbert-Slonzewski equation [1]. Here we study the dynamical behavior of a spin valve oscillator with a time dependent spin transfer torque coefficient. In particular, the electrical current has two terms, such that one has a quasiperiodic time dependence, while the other term is a constant one. We numerically characterize the dynamical behavior by monitoring the Lyapunov exponents, and by calculating Poincar sections and Fourier spectra [2]. We find a rather complicated landscape of sometimes closely intermingled chaotic and non-chaotic areas in parameters space. Finally, we show that the system exhibits strange nonchaotic attractors [3].

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Small amplitude chaotic patterns in parametrically driven weakly dissipative

7 Dec
09:00

Ronald Rivas[1,2] and David Laroze[1]

[1] Instituto de Alta de Investigación, Universidad de Tarapacá, Casilla 7D, Arica, Chile.
[2] Departamento de Física, Universidad Nacional Experimental Francisco de Miranda, Coro, Venezuela.

A generalized parametrically driven damped nonlinear Schrödinger equation is used to describe, close to the resonance, the dynamics of weakly dissipative systems, like a harmonically coupled pendula chain or an easy-plane magnetic wire [1,2]. The combined effects of parametric forcing, spatial coupling, and dissipation allows for the existence of stable non-trivial uniform states. We show that increasing the driving force each nontrivial uniform state suffers a spatial instability, and it becomes stationary pattern with small amplitude centered in the value of the previous homogeneous state. In addition, this stationary pattern can suffer a secondary bifurcation and it can become a chaotic pattern. We characterize the spatiotemporal behaviors through the largest Lyapunov exponent as well as bifurcation diagrams.

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Controlling the Multiplex PageRank through personalization vectors

7 Dec
09:00

R. Criado[1,2], E. García[1,2], F. Pedroche[3], Miguel Romance[1,2]

[1] Departamento de Matemática Aplicada, Universidad Rey Juan Carlos, C/Tulipán s/n, 28933 Móstoles (Madrid), Spain.
[2] Centre for Biomedical Technology, Technical University of Madrid, 28223 Pozuelo de Alarcón (Madrid), Spain.
[3] Institut de Matematica Multidisciplinaria, Universitat Politecnica de Valencia, 46022 Valencia, Spain

PageRank is the basic ingredient of the (probably) most famous web searcher (Google), but it also has many applications to different real-life problems, ranging from biological systems to cibersecurity. In this poster, a multiplex view of the classic PageRank is presented including some analytical relations between these new approach and the usual centrality measures. In addition to this, we will show how can we control the values of the PageRank of a node by tunning the personalization vectors and we will prove analytical results that give the sharp limits of this control.

Excitatory-inhibitory synaptic plasticity in a neuromorphic silicon neuron

7 Dec
09:00

Guillermo Savino, Carlos M. Formigli, Roberto Deza and Ignacio Deza
Departament of Electrónica, Facultad de Ciencias Exactas y Tecnología, Univ. Nacional de Tucumán, IFIMAR (CONICET) and Univ. Nacional de Mar del Plata, Argentina

We present a spiking and bursting with simple synapse circuit neuromorphic silicon neuron model that preserves dynamics of known types of cortical neurons. The model combines the biologically plausibility of Hodgkin-Huxley-type dynamics, the simplicity of integrate-and-fire neurons and real time working. The present circuit incorporates typical neuron postsynaptic potentials with excitatory and inhibitory effects graduating the probability to elicit spikes. The circuit postsynaptic potential changes, as real neurons do, with neuron activity (spiking rate) and with the many presynaptic inputs arriving from other neurons through dendrites. We test the circuit ability implementing Spike-Timing-Dependent Plasticity (STDP).

A novel Data Driven permutation entropy for discrete values

7 Dec
09:00

Francisco Traversaro Varela, Marcelo Risk, Osvaldo Rosso, Francisco Redelico
ITBA, CONICET-ITBA, Argentina

Bandt and Pompe introduced Permutation Entropy in 2002 for Time Series where equal values, $x_t^* = x_t, t^* = t$, were neglected and consider only inequalities between the x_t. Since then, this measure has been modified and extended, in particular in cases when the amount of equal values in the series can not be neglected, (i.e heart rate variability (HRV) time series). We review the different existing methodologies treating this subject by classifying them according to their different strategies. This classification resulted in three strategies: the first one, proposed in the Bandt and Pompe seminal paper, where equal values in the sequence are ignored. The second one deals with the issue by mapping the equal value onto the same symbol, extending the alphabet. The third one states that if two samples of the sequence are equal, they are ordered respect to time. We propose a new Bayesian methodology that uses the information of the actual time series. In this approach, the contribution of the sequences with ties to the non extended alphabet are supposed to have a certain a priori distribution. The results of this exhaustive exploration of these methods show that the Permutation Entropy estimation with the first strategy has a large variance as the number of sequence with equal values increases, while the strategy of modifying the alphabet greatly underestimate the Permutation Entropy. Ordering equal values in a sequence, according to time, results in a better estimation of the Permutation Entropy in both variance and bias. Regarding the Bayesian approach, using a non informative a priori distribution tends to overestimate the Permutation Entropy, while using a data-driven priori distribution to weight the contribution of the sequence with repeated values improves all the estimation of the above strategies. All this facts are illustrated by simulations and also by distinguishing patients suffering from Congestive Heart Failure from a (healthy) control group using HRV time series.

Matter-wave and optical solitons under the action of the spin-orbit coupling

7 Dec
09:35

Boris Malomed

Department of Physical Electronics, School of Electrical Engineering, Faculty of Engineering, Tel Aviv University, Tel Aviv 69978, Israel

Until recently, it was commonly believed that two-dimensional (2D) and three-dimensional (3D) mean-field models of atomic and optical waves with cubic attractive interactions could not produce stable fundamental solitons in the free space (i.e., without the use of an external confining or periodic potential), due to the occurrence of the critical collapse in the same setting. Solitons with embedded vorticity (vortex rings) are subject to a still stronger instability against azimuthal perturbations which split the rings. A novel finding is that the spin-orbit coupling (SOC) of the Rashba type gives rise to stable 2D solitons in the pseudo-spinor (two-component) Bose-Einstein condensate (BEC) [1]. It was also found that the SOC in the 2D system may be emulated in optics by the temporal dispersion of the linear coupling in dual-core planar waveguides with the Kerr self-focusing nonlinearity, which leads to the prediction of stable 2D spatiotemporal solitons ("light bullets") in the dual-core waveguide [2]. The stabilization is explained by the fact that the SOC terms break the specific scaling invariance of the 2D nonlinear Schrödinger/Gross-Pitaevskii equation, lift the respective degeneracy of the soliton family, and thus create otherwise missing ground states in the form of 2D solitons, which combine zero-vorticity and vortex terms. Effects of the SOC terms of the Dresselhaus type in the 2D pseudo-spinor BEC have been recently investigated too [3], with a conclusion that they tend to destroy the solitons. In the application to optics, the SOC-emulating terms may be combined with those emulating the parity-time (PT) symmetry (mutually balanced linear gain and loss in the cores of the dual-core waveguide), with a conclusion that 2D solitons have their stability region in the combined SOC-PT system too [4]. Finally, in the 3D free space the SOC interactions cannot create a missing ground state in the pseudo-spinor BEC, but they give rise to metastable solitons (which realize a local minimum of the Hamiltonian, being stable against small perturbations), also built as a mix of zero-vorticity and vortex terms. The talk aims to give an overview of these results, in the fields of BEC and nonlinear optics alike.

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Ultrashort Solitons that do not want to be too short in duration

7 Dec
10:10

Uwe Bandelow[1], Shalva Amiranashvili[1], and Nail Akhmediev[2]

[1] Weierstrass Institute for Applied Analysis and Stochastics (WIAS), Mohrenstr. 39, 10117 Berlin, Germany,

[2] Optical Sciences Group, Research School of Physics and Engineering, Institute of Advanced Studies, The Australian National University, Canberra ACT 2601, Australia

Too short optical solitons are destroyed most often due to influence of normal dispersion by virtue of Cherenkov radiation. However, sub-cycle solitons were never observed even for the most optimal dispersion profiles. Non-existence of sub-cycle solitons was demonstrated previously using analytic solutions for specially chosen linear [1,2]; and nonlinear [3] dispersion relations. In the absence of Cherenkov radiation another mechanism comes into play, namely, an unphysical cusp appears at the top of the pulse envelope and the soliton is destroyed. This happens at a critical duration of approximately 1.5 optical cycles. The cusp generation can be explained by representing solitary solutions ϕ of corresponding short-pulse-equations as homoclinic trajectories of a reduced dynamical system $\frac{1}{2}(\phi')^2 + U(\phi) = \text{const}$. The effective potential $U(\phi)$ depends on the choice of the short-pulse-equation and on additional parameters such as pulse duration. As the latter decreases the potential evolves and shows singular behavior. This phenomenon was found both for several available short-pulse-equations [2], and for the generalized NLSE [3]. The shortest soliton has a cusp shape and exhibits an algebraic power spectrum, rather than exponential decay [4]. Such peaked solitons have originally been found outside optics, for shallow water waves [5], which indicates universal behavior of this mechanism. Cusp existence was also confirmed in a general setting by direct numerical solution of Maxwell equations for several typical dispersion laws. We use a non-envelope bidirectional nonlinear wave equation with cubic nonlinearity and arbitrary dispersion [6].

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Anomalous diffusion of solitons in two spatial dimensions

7 Dec
11:15

Jaime Cisternas

Complex Systems Group, Facultad de Ingeniería y Ciencias Aplicadas, Universidad de los Andes, Santiago, Chile

Analyzing a model for the propagation of light pulses in nonlinear materials, we have discovered that the motion of the pulse in the transverse plane can become erratic, even in the absence of noise or external perturbations. These erratic or diffusive displacements, would normally follow the classic random walk description that predicts a mean squared displacement that grows linearly with time. Nevertheless in some situations we have observed statistics of the displacements that break the classic paradigm and indicate "anomalous diffusion". In this presentation I will explain the basic mechanism and show some of the consequences of the anomalies, in particular the "weak-ergodicity breaking", that forces us to reconsider most of the intuitions that one can possible hold about diffusive motion.

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Propagation of reaction diffusion fronts with gradient dependent diffusion

7 Dec
11:40

María Cristina Depassier and Rafael D. Benguria

Instituto de Física, Pontificia Universidad Católica de Chile

We study the asymptotic speed of traveling fronts of the scalar reaction diffusion $u_t = \partial_x(D(u,u_x)u_x) + f(u)$ for positive reaction terms f when the diffusion coefficient depends nonlinearly on the concentration and on its gradient. We restrict our study to diffusion coefficients of the form $D(u,u_x) = mu^{m-1}u_x^{m(p-2)}$. Such diffusion coefficients are encountered, for example, in hot plasmas [2,3] and are referred to as doubly nonlinear diffusion [1]. We formulate a variational principle for the asymptotic speed of the fronts from which upper and lower bounds can be obtained. We construct KPP type upper and lower bounds for the speed and an additional lower bound involving the integral of the reaction term, analogous to the classical Zeldovich-Frank Kamenetskii result [4].

More specifically we show that the speed can be estimated from

$$\left(\frac{mp}{p-1}\int_0^1 u^{(m-1)}f(u)du\right)^{(p-1)/p} \le c_*(m,p) \le p\left(\frac{m}{p-1}\right)^{(p-1)/p} \sup_u\left[u^\gamma\left(\frac{f}{u}\right)^{(p-1)}\right]^{1/p}.$$

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Chaotic convection in magnetic fluids

7 Dec
12:05

David Laroze[1] and Harald Pleiner[2]

[1] Instituto de Alta de Investigación, Universidad de Tarapacá, Casilla 7D, Arica, Chile,
[2] Max Planck Institute for Polymer Research, D 55021 Mainz, Germany

We report theoretical and numerical results on thermally driven convection of a magnetic suspension. The magnetic properties can be modeled as those of electrically non-conducting superparamagnets. We perform a truncated Galerkin expansion finding that the system can be described by a generalized Lorenz model [1]. We characterize the dynamical system using different criteria such as Fourier power spectrum, bifurcation diagrams, and Lyapunov exponents. We find that the system exhibits multiple transitions between regular and chaotic behaviors in the parameter space. Transient chaotic behavior in time can be found slightly below their linear instability threshold of the stationary state. Finally, we examine the generalized case when viscoelastic properties are taken into account [2].

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Information Theory Quantifiers as Indicators for Monitoring and Modelling of the Environment

8 Dec
09:00

Michael Hauhs[1], Sebastian Sippel[2], and Holger Lange[3]

[1] Ecological Modelling, University of Bayreuth, Bayreuth, Germany,
[2] Germany Max Planck Institute for Biogeochemistry, Jena, Germany,
[3] Norwegian Institute of Bioeconomy Research, Ås, Norway

Environmental problems have often lead to increased efforts of monitoring and modelling the corresponding dynamical systems. Time series of variables relevant for human use or for the understanding of these systems are the typical result. The processes generating these time series are in many examples poorly known. Here, we use measures quantifying the information content and complexity of modelled and observed time series to assess the dynamics. The aim is a classification of environmental time series, which is able to guide model-data comparisons. As an example we use the Gross Primary Productivity (GPP), a variable which tracks carbon uptake into terrestrial ecosystems and is hence relevant for climate models. We use information theory quantifiers to evaluate the differences in model structure from an intercomparison of 13 different land models (CMIP5 archive). Models which have been calibrated to a data set may still misrepresent the dynamics of the underlying system. We demonstrate that the proposed quantifiers are able to robustly separate among the models, but not among the various scenarios applied to them. This shows that the proposed data-analytical tools are suitable for model structural diagnostics.

Nonlinear Dynamics of streamflow from Brazilian rivers elucidated by Horizontal Visibility Graphs

8 Dec
09:35

Holger Lange[1] and Osvaldo A. Rosso[2,3,4]

[1] Norwegian Institute of Bioeconomy Research, Postboks 115, N-1431 Ås, Norway
[2] Instituto Tecnológico de Buenos Aires (ITBA), Ciudad Autónoma de Buenos Aires, Argentina
[3] Instituto de Física, Universidade Federal de Alagoas (UFAL), Maceió, Brazil
[4] Complex Systems Group, Facultad de Ingeniería y Ciencias Aplicadas, Universidad de los Andes, Santiago, Chile

We investigate a set of long-term (several decades) time series for the runoff at river gauges at daily resolution. They are monitored by the Agencia Nacional de Aguas, and time series provided by the Operador Nacional do Sistema Elétrico, Brazil. A total of 150 time series was obtained, with an average length of 73 years.

Both long-term trends as well as the influence of extreme events on the dynamical behaviour are analyzed. We use Horizontal Visibility Graphs (HVGs) to determine the individual temporal networks for the time series, and extract their degree distributions. Statistical and information-theoretic properties of these distributions are calculated: robust estimators of skewness and kurtosis, the maximum degree occurring in the time series, the Shannon entropy, permutation complexity and Fisher Information. For the latter, we also

compare the information measures obtained from the degree distributions to those using the original time series directly, to investigate the impact of graph construction on the dynamical properties as reflected in these measures. Focus is on one hand on universal properties of the HVG, common to all runoff series, and on site-specific aspects on the other.

We show that a specific pretreatment of the time series conventional in hydrology, the elimination of seasonality by a separate z-transformation for each calendar day, is highly detrimental to the nonlinear behaviour. It changes long-term correlations and the overall dynamic towards more random behaviour. Analysis based on the transformed data easily leads to spurious results, and bear a high risk of misinterpretation.

Foundations of Statistical Mechanics: Paradigms and consequences

8 Dec
10:10

Constantino Tsallis

Centro Brasileiro de Pesquisas Físicas (CBPF), Rio de Janeiro, Brazil &
Santa Fe Institute, Santa Fe, New Mexico, USA

Boltzmann-Gibbs (BG) statistical mechanics was formulated in the years 1870 and, together with Maxwell electromagnetism and classical, quantum and relativistic mechanics, constitutes one of the pillars of contemporary physics. As such it is world-wide studied in the courses of Physics, Chemistry, Computational Sciences, Economics, Biomedicine, Engineering, and more. This magnificent theory is based on the paradigm that the physical entropic functional is *unique* and additive, namely the BG one, which depends on no parameter at all. It was thought in 1985, and formally proposed in 1988, that this paradigm is not correct, and that it should be replaced by an adequate family of (nonadditive) entropies, thus reflecting various universality classes of natural, artificial and social complex systems. Today, three decades later, this simple idea has done a long and fruitful trajectory, and, as is natural, has also generated some controversies. A plethora of predictions and applications has concomitantly emerged through analytical, experimental, observational and computational results: nearly 6000 publications by over 12000 scientists are available in the Bibliography at `http://tsallis.cat.cbpf.br/biblio.htm`. A brief introduction of the central concepts, followed by various recent verifications of this generalization of the BG theory, will be presented.

Modelling Higher-order correlations in multi-neuron inputs and outputs in a population of neurons

8 Dec
11:15

Fernando Montani

IFLYSIB, CONICET & Universidad Nacional de La Plata, Calle 59-789, 1900 La Plata, Argentina

To understand how sensory information is processed in the brain, we need to investigate how information is represented collectively by the activity of a population of neurons. Information can be carried in spike rate, spike timing, and spike correlations across neurons. Spike correlations across neurons are widely found in the brain, and the evidences show that pairwise correlations do not by themselves account for multineuronal firing patterns. Indeed, the relationship between noise and signal correlations, when considering higher order correlations can lead either to redundancy or synergy at population level. Evidence shows that higher order correlations in the neuronal inputs and the spiking outputs follow a non-Gaussian statistics suggesting the need of developing a new theoretical framework taking into account the complexity of synchronous activity patterns. We analyze how input statistics are transformed through a threshold process into output statistics, and investigate the conditions that may lead to higher-order correlations in a neuronal ensemble. This allows us to define a new scenario for the interplay between pairwise and higher-than-pairwise interactions.

Dynamic Regime Criteria for Complex Network Reduction: Fertilization as Study Case

8 Dec
11:50

Gustavo Martínez-Mekler[1,2], Daniel Priego[1], Jess Espinal[3], Alejandro Aguado[1], and Alberto Darszon[4]

[1] Instituto de Ciencias Físicas, Universidad Nacional Autónoma de México (UNAM), Mexico
[2] Centro de Ciencias de la Complejidad (UNAM), Mexico
[3] Instituto Nacional de Medicina Genómica, Mexico
[4] Instituto de Biotecnología (UNAM), Mexico

The structure and dynamics of complex phenomena are often modeled by means of networks. In their study, the possibility of node reduction is commonly sought for. Here we present a strategy for such a reduction in terms of a discrete time attractor landscape analysis in conjunction with dynamical regime criteria. In doing so, we address issues such as robustness, redundancy, degeneracy, plasticity and criticality. As an exemplification, we analyze a signaling network for sea urchin flagellum calcium oscillations that controls sperm swimming during fertilization [1-4]. The recurrence of a critical dynamical regime after node deletions is challenging in evolutionary terms. A comparative study of the spread of initial condition perturbations as network nodes are deleted, by means of a modified version of the Derrida plot [5,6], identifies expansive (chaotic), contractive (regular) and marginal (critical) relative dynamics. This classification provides information that complements the attractor landscape analysis. Coincidence of the reduced network with an alternative continuous time formulation is encouraging. The reduction method is applicable to general logical networks.

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The space-time nature of causality

8 Dec
12:25

Murilo Da Silva Baptista

Institute for Complex Systems and Mathematical Biology, University of Aberdeen, King's College, AB24 3UE Aberdeen, UK

In a causal world the direction of the time arrow dictates how past causal events produce future effects. The determination of the direction and the intensity of the arrow of influence, causality, is one of the first questions one tries to answer in order to model a system. Given the relevance of the topic, several methods have been developed in the last decades to study causality. Among then, there are the approaches that access causality based on informational quantities. They are sustained by the fundamental idea if X causes an effect in Y, then uncertainty about future states of Y is reduced by considering the past of Y and the past of X, a hypothesis that implicitly adopts the Granger causal idea that observations in the past of both X (causing system) and Y (where the effect is produced) can be used to predict the future state of Y. This work aims at unifying the Granger definition of causality defined in terms of predictability with those based on information quantities by studying the dynamical fundamental of causality. We will show that a system X causes an effect in a system Y, if solely observations in Y can be used to predict the past states of the system X, an observation that will lead us to propose a new informational theoretic quantity to determine the direction of causal events that we name Causal Mutual Information. Along the way to demonstrate this fundamental intrinsic dynamical property of causality, we will show that causality has space and time signatures, and each signature can be advantageously explored to study the direction of influence in systems that are

being observed with different space-time resolutions, for example, time-series data of the environment or historical medical data of patients. Moreover, we will show that our quantity allows for a simple and less computational demanding approach, but rigorous, quantification of causality, and will illustrate its applicability by commenting on our currently developments to understanding causality in different natural, biological, and complex systems that our approach is being applied to.

Magneto-viscous effects on thermal convection in an Oldroyd magnetic fluid

8 Dec
14:00

D. Laroze[1], J. Bragard[2], L.M. Pérez[2], H.L. Mancini[2], P. Díaz[3], and Harald Pleiner[4]

[1] Instituto de Alta Investigación, Universidad de Tarapacá, Casilla 7D, Arica, Chile

[2] Departamento de Física y Matemática Aplicada, Universidad de Navarra, 31080 Pamplona, Spain

[3] Departamento de Ciencias Físicas, Universidad de La Frontera, Casilla 54-D, Temuco, Chile

[4] Max Planck Institute for Polymer Research, D 55021 Mainz, Germany

The purpose of the present paper is to analyze the influence of a magnetic field dependence of the viscosity on the convective threshold of viscoelastic magnetic fluids. As model systems we consider ferrofluids, suspensions of ferromagnetic particles in a carrier liquid, in the coarse-grained approximation, where particle diffusion and thermodiffusion are neglected. Such suspensions are often slightly visco-elastic, which we describe by a linear Oldroyd model

$$(1 + \lambda_1 \partial_t)\tau_{ij} = 2\nu_{eff}(1 + \lambda_2 \partial_t)A_{ij},$$

that contains relaxation of both, the stress τ_{ij} (λ_1) and the 'strain rate' $(1/2)(\nabla_j v_i + \nabla_i v_j) \equiv A_{ij}$ (λ_2), where the latter usually is referred to as retardation. The use of such models is rather popular, since viscoelasticity occurs in the form of a pseudo-constitutive equation and the structure of the hydrodynamic equations remains unchanged. The more physical description, suitable to generalizations to more complicated systems or to the nonlinear domain, introduces the elastic free energy in terms of the strain tensor, which constitutes an additional hydrodynamic degree of freedom. The relaxation of the latter describes viscoelasticity as transient elasticity. In the linear domain, both types of descriptions are equivalent, for the nonlinear domain cf. [1,2]. For magnetic suspensions, in particular highly concentrated ones, the visco-elastic properties can be magnetic field dependent. In this study, however, we concentrate on the magneto-viscous effect and take $\lambda_{1,2}$ as constants.

Magnetoviscosity is the dependence of the viscosity on the magnetic field and has the form [3]

$$\nu_{eff} = \nu_0(1 + \eta \boldsymbol{H}^2)$$

with a positive magnetoviscous coefficient η. At least for small fields this form is required by symmetry. Indeed, measurements on dilute ferrofluids confirm this field dependence for up to field strengths of $H \approx 10$ kA/m with a coefficient $\eta \approx 10^{-3}$ m^2/(kA)^2 for dilute suspensions. For very concentrated suspensions η can be higher by a factor of 5. For higher

fields the influence of the magnetic field saturates and $\eta \boldsymbol{H}^2$ in Eq. (2) has to be replaced by $\eta \boldsymbol{H}^2/(1+\tilde{\eta}\boldsymbol{H}^2)$. Theoretically, a field dependence of the form $\sim (\alpha - \sinh\alpha)/(\alpha+\sinh\alpha)$ with $\alpha \sim H$ has been given [3]. The maximum increase of the viscosity that can be obtained is about 10% - 30%. Although this looks like a small effect, its influence on the bifurcation behavior can be large, since this non-Boussinesq contribution breaks some symmetries of the underlying hydrodynamic equations.

For oscillating external magnetic fields, $\boldsymbol{H} = \boldsymbol{H}_0 \cos\omega t$, the magnetoviscous coefficient can be negative, with $\eta(\omega) = \eta_0(1-\omega^2\tau^2)/(1+\omega^2\tau^2)^2$ with τ the rotation frequency of the magnetic particles. This behavior also gives a hint on the microscopic mechanism that leads to the magneto-viscous effect: the external field hinders the free rotation of the magnetic particles and thereby increases the friction of the suspension *e.g.* for shear flow. In the case of magneto-rheological fluids (suspensions with large magnetizable particles) not only the effective viscosity and the visco-elasticity are dramatically increased by an external field, but also qualitatively new effects, like yield stress and thixotropy arise making Eqs. (1) and (2) unsuitable.

The remaining part of the hydrodynamics is that of an incompressible superparamagnet and has been given and applied to thermal convection previously [4,5,6]. The magnetization is treated statically and does not have its own dynamics. The magneto-viscous effect gives rise to two additional dimensionless numbers, $v_2 = \eta H^2$ and $v_1 = 2v_2\xi\Delta T$ showing up in the Oldroyd equation. Here, ξ is the thermomagnetic susceptibility $\xi = \chi_T/(1+\chi_0+\chi_H H^2)$ renormalized by the nonlinear magnetic susceptibility, arising from the magnetization $\delta\boldsymbol{M} = \chi_0\,\delta\boldsymbol{H} + \boldsymbol{H}(\chi_T\,\delta T + \chi_H \boldsymbol{H}\cdot\delta\boldsymbol{H})$ and ΔT is the temperature difference applied across the ferrofluid layer.

We will discuss stationary and oscillatory instabilities driven by the applied temperature gradient and the applied magnetic field for realistic boundary conditions using a spectral collocation method. The emphasis will be laid on the non-Boussinesq behavior due to the magneto-viscous effect.

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Identifying and characterizing regime transitions in complex dynamical systems

8 Dec
14:35

Cristina Masoller

Universitat Politècnica de Catalunya, Departament de Fisica, Colom 11, Terrassa, 08222

Complex systems often undergo abrupt or gradual transitions to dynamical regimes that can be safe or dangerous for the system functionality. Examples of dangerous transitions include desertification, population extinctions, financial crashes, cardiac arrhythmia, epileptic seizures, etc. A precise identification of such transitions is important for preventing harmful consequences, and a lot of efforts are nowadays focused on developing reliable diagnostic tools that can be applied to observed time-series. In this presentation I will discuss our recent work aimed at using complex network tools and symbolic time-series analysis for characterizing and quantifying regime transitions in different dynamical systems [1-3]. References

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(Non)-universality of vortex reconnections in superfluids

8 Dec
15:30

Alberto Villois[1], Giorgio Krstulovic[2], and Davide Proment[1]

[1] School of Mathematics, University of East Anglia, Norwich Research Park, Norwich, NR4 7TJ, United Kingdom.
[2] Université de la Côte d'Azur, OCA, CNRS, Lagrange, France. B.P. 4229, 06304 Nice Cedex 4, France

Vortex reconnections play a fundamental role in fluid dynamics. In superfluids, vortices are topological defects of the order parameter and their circulation is quantized. Due to the Kelvin theorem, reconnections can not take place in an inviscid flow. However, despite the lack of dissipation, quantum vortices do reconnect because the density of the order parameter vanishes at the vortex-core. These quantum vortices have an extremely thin core which makes them an excellent theoretical framework.

In this talk, an insight into vortex reconnections in superfluids is presented making use of analytical results and numerical simulations of the Gross–Pitaevskii model. The universal aspects of vortex reconnection are investigated by considering different initial vortex configurations and making use of a recently developed vortex tracking algorithm. It is shown

that close to reconnection events, vortex lines approach and separate always accordingly to the (simplest) dimensional time scaling $t^{1/2}$, with pre-factors that depend on the vortex configuration. The behaviour of curvature and torsion of vortex filaments close to the reconnection point is studied, demonstrating analytically that the curvature exhibits an asymptotic self-similar behaviour and the torsion may develop shock-like structures. Such shock-like structures of torsion are responsible for breaking down the self-similarity of curvature.

Self-organization theories as explanation of fairy circle formation: Turing-pattern versus localized structures

8 Dec
15:55

Daniel Escaff[1], Mustapha Tlidi[2], Cristián Fernández-Oto[2] and Marcel Clerc[3]

[1] Facultad de Ingeniería y Ciencias Aplicadas, Universidad de los Andes, Santiago, Chile
[2] Université Libre de Bruxelles, Bruxelles, Belgium
[3] Universidad de Chile, Santiago, Chile

Mysterious circular areas devoid of any vegetation are often observed in vast zones in southern Angola, Namibia, and South Africa. Since the unknown origin of theses structures, they are called fairy circles. Even through, many hypothesis have been proposed to explain its formation, none of them have been majority accepted by the community devoted to the topic. One subgroup of these theories is the ones that are based on the self-organization hypothesis. They attribute the fairy circles formation to the plant interaction due to different mechanisms as: competition for resources; facilitation or cooperative interaction; and seed dispersal. According to the self-organization hypothesis, all these interactions lead to a nonlinear evolution of the biomass, which explains its spatially heterogeneous distribution. There is, however, the tendency to confuse all the self-organization mechanisms into the same category: namely, the Turings theory of morphogenesis. The aim of this talk is to establish a neat differentiation between two self-organization mechanisms: Turing-pattern versus localized states induced by strong nonlocal coupling. Compare them, and their predictions and implications for fairy circles formation.

Correlations in a Bose-Fermi mixture

8 Dec
16:20

Pablo Díaz[1], David Laroze[2], and Boris A. Malomed[3]

[1] Departamento de Ciencias Físicas, Universidad de La Frontera, Casilla 54D, Temuco, Chile,
[2] Instituto de Alta Investigación, Universidad de Tarapacá, Casilla 7D, Arica, Chile,
[3] Department of Physical Electronics, School of Electrical Engineering, Faculty of Engineering, Tel Aviv University, Tel Aviv 69978, Israel

We study a BoseFermi mixture within the framework of the mean-field theory, including three possible regimes for the fermionic species: fully polarized, BCS, and unitarity. Starting from the 3D description and using the variational approximation (VA), we derive one-dimensional and two-dimensional systems of equations, under the corresponding confining potentials. This method produces a pair of nonlinear Schrödinger equations coupled to algebraic equations for the transverse widths of the confined state. The equations incorporate interactions

between atoms of the same species and between the species, assuming that the latter can be manipulated by means of the Feshbach resonance. As an application, we explore spatial density correlations in the ground state (GS) between the species, concluding that they strongly depend on the sign and strength of the inter-species interaction. Also studied are the dynamics of the mixture in a vicinity of the GS and the corresponding spatiotemporal inter-species correlation. The correlations are strongly affected by the fermionic component, featuring the greatest variation in the unitary regime. Results produced by the VA are verified by comparison with full numerical solutions.

Enhanced rectification of a superfluid motion in the presence of a biharmonic force

8 Dec
16:45

Luis Morales-Molina and Edward Arévalo

Facultad de Física, Pontificia Universidad Católica de Chile, Santiago, Chile

We study the superfluid behavior motion of interacting particles in a periodic potential subjected to the presence of an external biharmonic force. We focus our analysis on relevant *nonlinear Floquet-Bloch states* within the mean field approximation that display loops in the energy spectrum. The formation of loops is a hallmark of a transition where the superfluid motion overcomes the periodic potential. We find that the direction of the superfluid motion can be controlled by tuning the relative phase between the two harmonics of the external force. Moreover, a great enhancement of the rectified current is achieved by exploting the interaction among particles. We also show that the flux of particles induced by broken ac-fields can be used as a detection tool of the transition point where the superfluid behavior overcomes the optical lattice.

Effects of network heterogeneity in agent-based models

9 Dec
09:00

Raúl Toral

Instituto de Física Interdisciplinar y Sistemas Complejos, IFISC (CSIC-UIB), Campus UIB, 07122 Palma de Mallorca, Spain

Some of the modern applications of Statistical Physics to problems of interest in social and economical systems, amongst others, use agent-based models in which actors live in the nodes of a network and interact through active links. For simplicity most approaches use a homogeneity condition, namely that all agents behave in the same way. In this contribution we want to review recent work which focuses on the effect that the heterogeneity of the network –the fact that not all agents have the same number of interactions– and the heterogeneity of agents themselves, have on the collective, observable, outcome of the dynamics. We will exemplify this by the use of some well-known models, as the SIS (susceptible-infected-susceptible) model for transmission of epidemics and the noisy-voter model, also known as the Kirman model for the behavior of financial markets.

Cryptocurrency analysis using information theory quantifiers

9 Dec
09:35

Aurelio F. Bariviera[1] and Osvaldo A. Rosso[2,3]

[1] Department of Business, Universitat Rovira i Virgili, Reus, Spain
[2] Instituto de Física, Universidade Federal de Alagoas, Maceió, Alagoas, Brazil
[3] Complex Systems Group, Facultad de Ingeniería y Ciencias Aplicadas, Universidad de los Andes, Santiago, Chile

Many economic data are recorded as a sequence of measurements equally spaced in time. This kind of data, commonly referred as time series, are usually the starting point for economic analysis. In this line, information-theory-derived quantifiers can help to extract relevant information from financial time series. When studying dynamical systems, the discrimination of the presence of correlations in time series, emerges as one key task. In aecent paper, Bariviera et al. (2015) proposed the joint use of the Shannon entropy and the Fisher Information Measure, as a proxy for informational efficiency. In another paper Bariviera et al. (2016) shows that the Complexity-Entropy Causality Plane constitutes a powerful graphical tool in order to discriminate stochastic and chaotic dynamics. Another element to take into account when studying time series is the probability density function estimation. We show that the use of the symbolic technique proposed by Bandt and Pompe (2002) is very useful in econophysics given its robustness to observational noise and absence of a priori assumptions. In this paper we extend our previous analysis, providing evidence that sampling frequency can uncover some additional characteristics of financial time series. We apply our technique to a time series of bitcoin prices, in order to understand the behavior of this cryptocurrency.

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Self-organized vegetation patches and fairy circles in a resource-limited environment

9 Dec
10:10

Mustapha Tlidi[1], Ignacio Bordeu[2], Daniel Escaff[3], and Marcel Clerc[4]

[1] Université Libre de Bruxelles, Bruxelles, Belgium
[2] Imperial College London, UK
[3] Universidad de los Andes, Santiago, Chile
[4] Universidad de Chile, Santiago, Chile

Desertification is a central problem in both ecology and economy. Incerasing drought periods and climate change allow vegetations to survive in scarce environments. Understanding how vegetation manages to survive and to propagate through arid and semiarid ecosystems may be useful in the development of future strategies to prevent desertification.

In this communication, we present some field observations and we focus on patterns of vegetation that are visible in nature at various spatial scales. Patterns of vegetation biomass are typical of arid regions where the potential evapotranspiration substantially exceeds the mean annual precipitation. This hydric deficit impedes the development of individual plants and, at the community level, promotes clustering behaviors which, via a modulational instability, take shape even if the topography is isotropic. We present and discuss the effect of non-local coupling that models the facilitation and the competition between individual plants. We then apply this mechanism to localized patches of vegetation. We develop a statistical analysis based on real data taking from field observations to show that patches may exhibit deformation and splitting. This growth mechanism is opposite to the desertification since it allows to repopulate territories devoid of vegetation. We investigate these aspects by characterizing quantitatively, with a simple mathematical model, a new class of instabilities that lead to the self-replication phenomenon observed.

In the last part, we discuss the formation of fairy circles that consist of isolated or randomly distributed circular areas devoid of any vegetation. They are observed in vast territories in southern Angola, Namibia, and South Africa. We report on the formation of fairy circles and we interpret them as localized structures with a varying plateau size as function of the aridity. Their stabilization mechanism is attributed to a combined influence of the bistability between the bare state and the uniformly vegetation state, and Lorentzian-like non-local coupling that models the competition between plants. We show how a circular shape is formed, and how the aridity level influences the size of fairy circles.

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Chaotic Dynamics in Diode Lasers: Correlations in Synchronization

9 Dec
11:15

José Roberto Rios Leite

Departamento de Fisica, Universidade Federal de Pernambuco, Recife, Brazil

We shall discuss the correlations within the synchronization among chaotic systems and their dependence with time scales. Experiments in a pair of Semiconductor diode laser give evidence to simultaneous manifestation of anti-phase and in-phase power fluctuations when the lasers share a common current source.

Classification and Verification of Handwritten Signatures with Time Causal Information Theory Quantifiers

9 Dec
11:50

Osvaldo A. Rosso[1,2], Raydonal Ospina[3], Alejandro C. Frery[4]

[1] Instituto Tecnológico de Buenos Aires (ITBA), Ciudad Autónoma de Buenos Aires, Argentina
[2] Instituto de Física, Universidade Federal de Alagoas (UFAL), Maceió, Brazil
[3] Departamento de Estatística, Universidade Federal de Pernambuco (UFPE), Recife, Brasil
[4] Instituto de Computação, Universidade Federal de Alagoas (UFAL), Maceió, Brazil

We present a new approach for handwritten signature classification and verification based on descriptors stemming from time causal Information Theory. The proposal uses the Shannon Entropy, the Statistical Complexity, and the Fisher Information evaluated over the Bandt and Pompe symbolization of the horizontal and vertical coordinates of signatures. These six features are easy and fast to compute, and they are the input to an One-Class Support Vector Machine classifier. The results produced surpass state-of-the-art online techniques that employ higher-dimensional feature spaces which often require specialized software and hardware. We assess the consistency of our proposal with respect to the size of the training sample, and we also use it to classify the signatures into meaningful groups.

List of Participants

Jaime Anguita
Facultad de Ingeniería y Ciencias Aplicadas,
Universidad de los Andes, Santiago, Chile
janguita@miuandes.cl

Edward Arévalo
Facultad de Física,
Pontificia Universidad Católica de Chile, Santiago, Chile
earevalo@fis.puc.cl

Miguel Arizmendi
Departamento de Física, Facultad de Ingeniería,
Universidad de Mar del Plata, Mar del Plata, Argentina
arizmend@fi.mdp.edu.ar

Uwe Bandelow
Group Laser Dynamics,
Weierstrass Institute for Applied Analysis and Stochastics, Berlin, Germany
Uwe.Bandelow@wias-berlin.de

Murilo Da Silva Baptista
Institute for Complex Systems and Mathematical Biology,
University of Aberdeen, Aberdeen, UK
murilo.baptista@abdn.ac.uk

Rafael Benguria
Pontificia Universidad Católica de Chile
Santiago, Chile
rbenguri@fis.puc.cl

Francisca Bown
CECS, Valdivia, Chile
fbown@cecs.cl

Helmut Brand
University of Bayreuth, 95440 Bayreuth, Germany
brand@uni-bayreuth.de

Javier Burguete
Departamento de Física y Matemática Aplicada,
Universidad de Navarra, Navarra, Spain
javier@fisica.unav.es

Ana Cabanas
Instituto de Alta Investigación
Universidad de Tarapacá, Arica, Chile
ana.cabanas.plana@gmail.com

Carlos Cartes
Facultad de Ingeniería y Ciencias Aplicadas,
Universidad de los Andes, Santiago, Chile
ccartes@gmail.com

Paulo M. Centres
Departamento de Física, Instituto de Física Aplicada,
Universidad Nacional de San Luis-CONICET, San Luis, Argentina
pcentres@unsl.edu.ar

Jaime Cisternas
Facultad de Ingeniería y Ciencias Aplicadas,
Universidad de los Andes, Santiago, Chile
jecisternas@miuandes.cl

Edgardo Comas
Institute of Scientific and Technical Research for Defense, Buenos Aires, Argentina
ecomas@citedef.gob.ar

Regino Criado Herrero
Departamento de Matemática Aplicada, Universidad Rey Juan Carlos, Madrid, Spain
regino.criado@urjc.es

María Cristina Depassier
Pontificia Universidad Católica de Chile
Santiago, Chile
mcdepass@fis.puc.cl

Orazio Descalzi
Facultad de Ingeniería y Ciencias Aplicadas,
Universidad de los Andes, Santiago, Chile
odescalzi@miuandes.cl

Pablo Díaz
Departamento de Ciencias Físicas, Universidad de La Frontera,
Temuco, Chile
pablo.diaz@ufrontera.cl

Daniel Escaff
Facultad de Ingeniería y Ciencias Aplicadas,
Universidad de los Andes, Santiago, Chile
descaff@miuandes.cl

Aurelio Fernández Bariviera
Department of Business, Universitat Rovira i Virgili, Reus, Spain
aurelio.fernandez@urv.net

Carlos Formigli
Universidad Nacional de Tucumán, Tucumán, Argentina

cformigli@herrera.unt.edu.ar

Theo Geisel
Max-Planck Institute for Dynamics and Self-Organization, Göttingen, Germany
Department of Physics, Georg August University Göttingen, Germany
geisel@nld.ds.mpg.de

Mariela González
Universidad Nacional de San Luis, San Luis, Argentina
migonzalez@unsl.edu.ar

Pablo Gutiérrez
Universidad de Chile
Santiago, Chile
pagutier@gmail.com

Michael Hauhs
Ecological Modelling, University of Bayreuth, Bayreuth, Germany
michael.hauhs@uni-bayreuth.de

Henar Herrero
Instituto de Matemática Aplicada a la Ciencia y la Ingeniería (IMACI),
Dpto. de Matemáticas, Facultad de Ciencias y Tecnologías Químicas
Universidad de Castilla-La Mancha, Ciudad Real, Spain
Henar.Herrero@uclm.es

Fernando R. Humire
Instituto de Física, Pontificia Universidad Católica de Valparaíso, Chile.
fer.mellado.humire@gmail.com

Gladys Jara Schulz
Instituto de Física, Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile
r8.gladys@gmail.com

Giorgio Krstulovic
Observatoire de la Côte d'Azur
Nice, France
krstulovic@oca.eu

Jürgen Kurths
Potsdam Institute for Climate Impact Research, Potsdam, Germany
Juergen.Kurths@pik-potsdam.de

Holger Lange
Norwegian Institute of Bioeconomy Research, Ås, Norway
Holger.Lange@nibio.no

David Laroze
Instituto de Alta Investigación, Universidad de Tarapacá,
Arica, Chile

david.laroze@gmail.com

José Roberto Rios Leite
Departamento de Fisica, Universidade Federal de Pernambuco, Recife, Brasil
rios@df.ufpe.br

Walter Lebrecht Díaz-Pinto
Departamento de Ciencias Físicas
Universidad de La Frontera
Temuco, Chile
walter.lebrecht@ufrontera.cl

Walter Legnani
Signals and Image Processing Center (CPSI), Universidad Tecnológica Nacional,
Buenos Aires, Argentina
walterlegnani@gmail.com

Katja Lindenberg
Department of Chemistry and Biochemistry,
University of California, San Diego, La Jolla, USA,
klindenberg@ucsd.edu

Magdalena Lucini
Facultad de Ciencias Exactas, Naturales y Agrimensura, Universidad Nacional del Nordeste,
Corrientes, Argentina
magdalenalucini@gmail.com

Boris Malomed
The Faculty of Engineering, Tel Aviv University, Tel Aviv, Israel
malomed@post.tau.ac.il

Cristina Masoller
Departament de Física i Enginyeria Nuclear,
Universitat Politècnica de Catalunya, Terraza, Barcelona, Spain
cristina.masoller@upc.edu

Gustavo Martínez-Mekler
Instituto de Ciencias Físicas, UNAM, Cuernavaca, Mexico
mekler@icf.unam.mx

Gabriel Mindlin
Departamento de Física, Universidad de Buenos Aires (UBA),
Ciudad Autónoma de Buenos Aires, Argentina
gabo.mindlin@gmail.com

Paula Mellado
Universidad Adolfo Ibáñez
Santiago, Chile
paula.mellado@uai.cl

Fernando Montani
Instituto de Física de Líquidos y Sistemas Biológicos,
Universidad Nacional de La Plata, La Plata, Argentina
fmontani@gmail.com

Luis Morales-Molina
Facultad de Física,
Pontificia Universidad Católica de Chile,
Santiago, Chile
lmolina@fis.puc.cl

Cristian Mourkarzel
CINVESTAV, Mérida, Mexico
cristian@mda.cinvestav.mx

Nicolás Mujica
Universidad de Chile
Santiago, Chile
nmujica@dfi.uchile.cl

Felipe Olivares
Instituto de Física, Pontificia Universidad Católica de Valparaíso (PUCV), Valparaíso, Chile
olivaresfe@gmail.com

Laura M. Pérez
Instituto de Alta Investigación, Universidad de Tarapacá,
Arica, Chile
fuentes.lauraperez@gmail.com

Harald Pleiner
Max Planck Institute for Polymer Research, Mainz, Germany
pleiner@mpip-mainz.mpg.de

Manuel Pulido
Universidad Nacional del Nordeste
Corrientes, Argentina
pulido@exa.unne.edu.ar

Günter Radons
Komplexe Systeme und Nichtlineare Dynamik,
Technische Universität Chemnitz, Chemnitz, Germany
radons@physik.tu-chemnitz.de

Sergio Rica
Universidad Adolfo Ibáñez
Santiago, Chile
sergio.rica@uai.cl

Ronald Rivas

Instituto de Alta de Investigación, Universidad de Tarapacá,
Arica, Chile
r.rivas.suarez@gmail.com

Miguel Romance
Departamento de Matemática Aplicada, Universidad Rey Juan Carlos, Madrid, Spain
miguel.romance@urjc.es

Osvaldo A. Rosso
Departamento de Bioingeniería, Instituto Tecnológico de Buenos Aires,
Ciudad Autónoma de Buenos Aires, Argentina
oarosso@gmail.com

Harm Hinrich Rotermund
Department of Physics and Atmospheric Science, Dalhousie University, Halifax, Canada
harm.rotermund@dal.ca

Guillermo Savino
Departamento de Electrónica, Facultad de Ciencias Exactas y Tecnología, Univ. Nacional de Tucumán, IFIMAR (CONICET) &
Univ. Nacional de Mar del Plata, Mar del Plata, Argentina
gsavino@herrera.unt.edu.ar

Mustapha Tlidi
Department of Physics, Université Libre de Bruxelles, Brussels, Belgium
mtlidi@ulb.ac.be

Raúl Toral
Instituto de Física Interdisciplinar y Sistemas Complejos (IFISC),
Universitat de les Illes Balears, Palma de Mallorca, Spain
raul@ifisc.uib-csic.es

Francisco Traversaro
ITBA, CONICET-ITBA
Buenos Aires, Argentina
ftraversaro@itba.edu.ar

Constantino Tsallis
Centro Brasileiro de Pesquisas Físicas (CBPF), Rio de Janeiro, Brazil &
Santa Fe Institute, Santa Fe, New Mexico, USA
tsallis@cbpf.br

R.S. Wedemann
Instituto de Matemática e Estatística, Universidade do Estado do Rio de Janeiro (UERJ)
Rio de Janeiro, Brazil
roseli@ime.uerj.br

Author Index