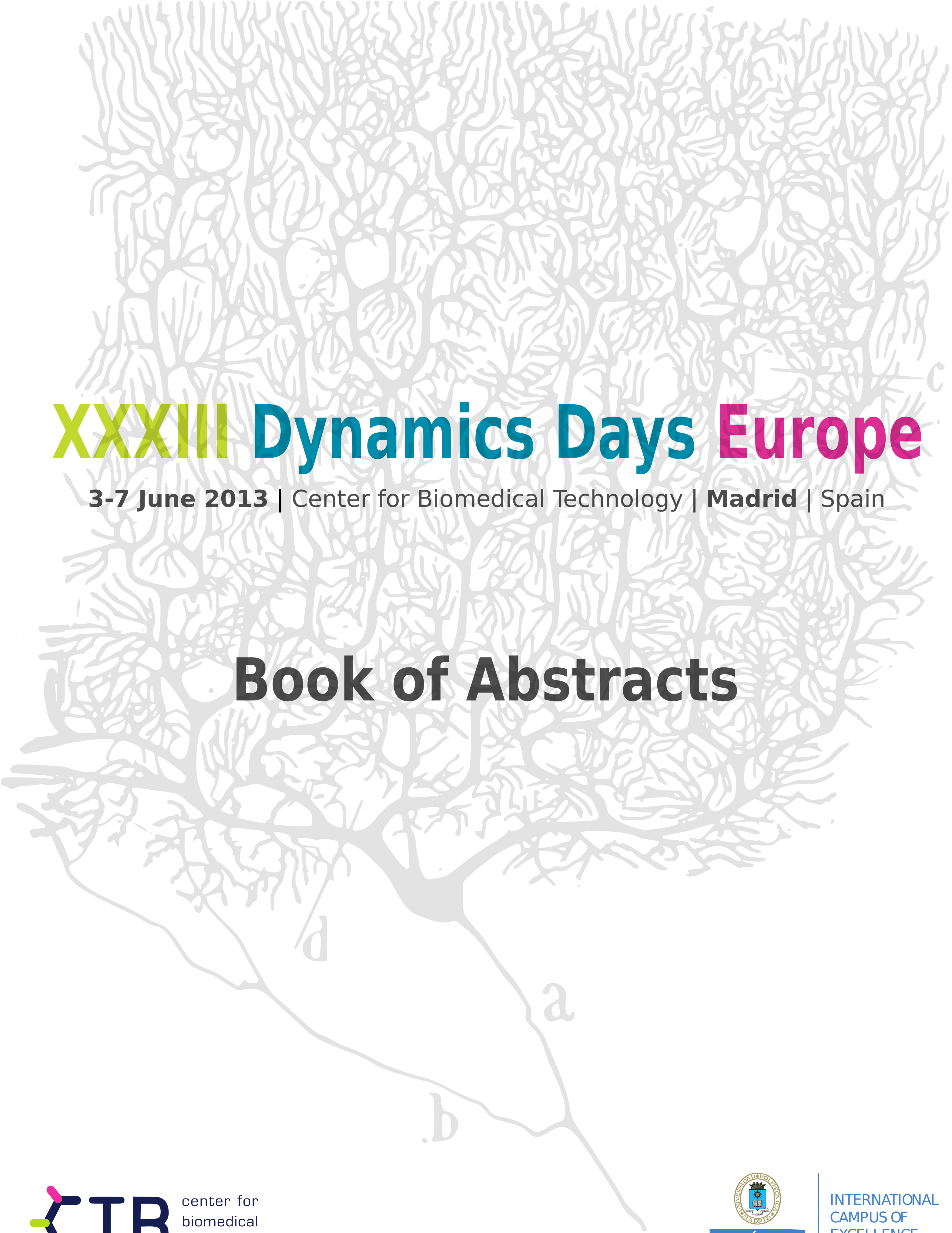

XXXIII Dynamics Days Europe

3-7 June 2013 | Center for Biomedical Technology | **Madrid** | Spain

Book of Abstracts

center for biomedical technology

POLITÉCNICA "Engineering the future"

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1. Non-linear Dynamics
Computer Science School U.P.M.
Campus de Montegancedo
28660 Boadilla del Monte, Madrid

POLITÉCNICA
FUNDACIÓN GENERAL
UNIVERSIDAD POLITÉCNICA DE MADRID

Program at a Glance

	Sunday, June 2	Monday, June 3	Tuesday, June 4
8.45-9.00		BUSES ARRIVAL	BUSES ARRIVAL
9.00-9.15		REGISTRATION AND OPENING	**Room 1: PT3** TBA *Jordi García-Ojalvo*
9.15-9.30			
9.30-9.45			
9.45-10.00		**Room 1: PT1** Synchronization in Populations of Chemical Oscillators *Kenneth Showalter*	**Room 1: PT4** Evolution on genotype networks leads to phenotypic entrapment *Susanna C. Manrubia*
10.00-10.15			
10.15-10.30			
10.30-10.45		COFFEE BREAK	COFFEE BREAK
10.45-11.00			
11.00-11.45		**Room 1: MS1** Processes on Complex Networks **Room 2: MS2** Brain I **Room 3: MS3** Lasers I **Room 4: MS4** Cardiac Electromechanical **Room 5: MS5** Genetic Circuits	**Room 1: MS6** Networks of Oscillators **Room 2: MS7** Localized Structures of Light I **Room 3: MS8** Lasers II **Room 4: MS9** Cardiac Electrophysiology **Room 5: MS10** Particles in Turbulent Flows
11.45-12.00			
12.00-12.15			
12.15-12.30			
12.30-12.45			
12.45-13.00			
13.00-13.15		LUNCH BREAK	LUNCH BREAK
13.15-13.30			
13.30-13.45			
13.45-14.00			
14.00-14.15		**Room 1: PT4** Importance of nonlinear features in continuous theories of active matter *Hugues Chaté*	**Room 1: MS11** Coupled Oscillators **Room 2: MS12** Living Systems **Room 3: MS13** Vegetation Patterns in Ecosystems **Room 4: MS14** Quantum-Chaotic Dynamics **Room 5: MS15** Molecules Through Bottlenecks
14.15-14.30			
14.30-14.45			
14.50-15.00		**Room 1: CT1** Networks I **Room 2: CT2** Pattern formation and dynamics **Room 3: CT3** Social networks **Room 4: CT4** Neural dynamics **Room 5: CT5** Transport phenomena	
15.00-15.15			
15.15-15.30			
15.30-15.45			COFFEE BREAK
15.45-16.00			POSTER AND WINE SESSION
16.00-16.15			
16.15-16.30			
16.30-16.45		COFFEE BREAK	
16.45-17.00			
17.00-17.15		**Room 1: CT6** Synchronization **Room 2: CT7** Methods in nonlinear dynamics **Room 3: CT8** Delayed systems **Room 4: CT9** Fluids and granular media **Room 5: CT10** Quantum and hamiltonian systems	
17.15-17.30			
17.30-17.45			
17.45-18.00			
18.00-18.15	REGISTRATION AT NH ABASCAL HOTEL		
18.15-18.30			
18.30-18.40			
18.40-19.00		BUSES DEPARTURE	BUSES DEPARTURE
19.00-20.00			

	Wednesday, June 5	Thursday, June 6	Friday, June 7
8.45-9.00	BUSES ARRIVAL	BUSES ARRIVAL	BUSES ARRIVAL
9.00-9.15	**Room 1: PT5** A new metrics for the economic complexity of countries and productss *Luciano Pietronero*	**Room 1: PT9** Mechanism of Dissipation in Turbulent Quantum Fluids at Ultra Low Temperatures *Itamar Procaccia*	**Room 1: PT12** Meso-scale structures induce characteristic instabilities in networks of coupled dynamical systems *Anne Ly Do*
9.15-9.30			
9.30-9.45			
9.45-10.00	**Room 1: PT6** Model studies of electron transfer and conduction mediated by solitons in 1D and 2D crystal lattices *Manuel G. Velarde*	**Room 1: PT10** Distinguishing Signatures of Determinism and Stochasticity in Spiking Complex Systems *Cristina Masoller*	**Room 1: PT13** Time as coding space for information processing in the cerebral cortex *Wolf Singer*
10.00-10.15			
10.15-10.30			
10.30-10.45	COFFEE BREAK	COFFEE BREAK	COFFEE BREAK
10.45-11.00			
11.00-11.45	**Room 1: MS16** Delay-Coupled Networks **Room 2: MS17** Localized Structures of Light II **Room 3: MS18** Multiscale Pattern Formation **Room 4: MS19** Social and Ecological Networks **Room 5: MS20** Dissipative Solitons	**Room 1: MS21** Dynamics of Multistable Systems **Room 2: MS22** Stochastic Population Dynamics **Room 3: MS23** Time Series and Causality Networks **Room 4: MS24** Solitons and Fronts in Fiber Resonators **Room 5: MS25** Extreme Events	**Room 1: MS26** Climate Networks **Room 2: MS27** Multiplex and Evolutive Networks **Room 3: MS28** Control of Nonlinear Systems **Room 4: MS29** Dynamics of Hearing **Room 5: MS30** Brain II
11.45-12.00			
12.00-12.15			
12.15-12.30			
12.30-12.45			
12.45-13.00			
13.00-13.15	LUNCH BREAK	LUNCH BREAK	CLOSING
13.15-13.30			
13.30-13.45			
13.45-14.00			LUNCH BREAK
14.00-14.15	**Room 1: PT7** The Fragility of Interdependency: Coupled Networks & Switching Phenomena *H. Eugene Stanley*	**Room 1: PT11** Taming Complexity: Controlling Networks *Albert-Lázló Barabási*	
14.15-14.30			
14.30-14.45			BUSES DEPARTURE
14.50-15.00	**Room 1: PT8** Quantifying gene-circuit dynamics at the single-cell level *Mitchell J. Feigenbaum*	**Room 1: CT11** Networks II **Room 2: CT12** Dynamics of coupled oscillators **Room 3: CT13** Nonlinear optics and lasers **Room 4: CT14** Spatio-temporal dynamics **Room 5: CT15** Biophysics and biomedicine	
15.00-15.15			
15.15-15.30			
15.30-15.45	COFFEE BREAK		
15.45-16.00			
16.00-16.15	EXCURSION AND CONFERENCE DINNER		
16.15-16.30		COFFEE BREAK	
16.30-16.45			
16.45-17.00		**Room 1: CT16** Chaos **Room 2: CT17** Stochastic processes **Room 3: CT18** Biological and ecological systems **Room 4: CT19** Statistical physics **Room 5: CT20** Fluid dynamics	
17.00-17.15			
17.15-17.30			
17.30-17.45			
17.45-18.00			
18.00-18.15			
18.15-18.30			
18.30-18.40			
18.40-19.00		BUSES DEPARTURE	

EXTENDED PROGRAM

Registration and Opening 9.00–9.45

PT1: Plenary talk *Chair: I. Sendiña-Nadal* 9.45–10.30
Synchronization in populations of chemical oscillators: Quorum Sensing, phase clusters and chimeras *Kenneth Showalter* Room 1

Coffee break 10.30–11.00

MS1: Dynamical processes on complex networks 11.00–13.00
Organizers: D. Gómez-Ullate and J. Aguirre Room 1
Chair: D. Gómez-Ullate and J. Aguirre

1. **Synchronization in contact networks of mobile oscillators** *Albert Diaz-Guilera*
2. **Using Friends as Sensors to Detect Global-Scale Contagious Outbreaks** *Esteban Moro*
3. **Competition between complex networks: phenomenology and winning strategies** *Jacobo Aguirre*
4. **Search for optimal function in RNA populations evolving over networks of genotypes** *Michael Stich**

MS2: Characterizing neuronal interactions and synchronization in the brain dysfunction epilepsy 11.00–13.00
Organizers: R. G. Andrzejak Room 2
Chair: R.G. Andrzejak

1. **Focusing outside the focus the causes of focal seizures** *Guillermo José Ortega*
2. **Dynamic markers of epileptogenesis and seizures at multiple scales** *Liset Menendez de la Prida*
3. **Brain connectivity during epileptiform discharges is altered by TMS** *Dimitris Kugiumtzis*
4. **Electroencephalographic signals from seizure-generating brain areas: less randomness, more nonlinear-dependence, and more stationarity** *Ralph Gregor Andrzejak*

MS3: Nonlinear dynamics in lasers: Fundamental Issues and Novel Applications I 11.00–13.00
Organizers: K. Lüdge and C. Masoller Room 3
Chair: K. Lüdge

1. **Dynamics of single- and double-contact hybrid-cavity semiconductor lasers under fast frequency tuning by an intracavity filter** *Eugene Avrutin*
2. **Oscillatory and excitable dynamics of dissipative solitons in optical cavities** *Pere Colet*
3. **Nonlinear dynamics in semiconductor ring lasers** *Jan Danckaert*
4. **Nonlinear dynamics in VCSELs with crossed polarization reinjection** *Massimo Giudici*

MS4: Cardiac electromechanical modeling 11.00–13.00
Organizers: S. Filippi and A. Gizzi Room 4
Chair: S. Filippi

1. **Theoretical electromechanics of cardiac tissue** *Alessio Gizzi*
2. **Suitable numerical methods and related modeling issues in the study of cardiac electromechanics** *Ricardo Ruiz Baier*
3. **Modeling anisotropic myocardial contractions** *Luciano Teresi*
4. **Atrial flutter: a model for studying mechano-electrical coupling in the human heart** *Michaella Masè*

MS5: Nonlinear dynamics of genetic circuits 11.00–13.00
Organizers: E. Volkov and E. Ullner Room 5
Chair: E. Ullner

1. **Emergence of oscillations in communicating bacteria** *Krasimira Todorova Tsaneva-Atanasova*
2. **The role of noise in dynamics of repressilator with quorum sensing** *Ilya Potapov*
3. **Dynamics of the quorum sensing switch: stochastic and non-stationary effects** *Marc Weber*
4. **Re-engineering a genetic circuit into a synthetic tunable oscillator.** *Lucia Marucci*

Lunch break 13.00–14.00

14.00–14.45 **PT2: Plenary talk** *Chair: M. Zanin*
Room 1 **Importance of nonlinear features in continuous theories of active matter** *Hugues Chaté*

14.50–16.30 **CT1: Networks I**
Room 1 *Chair: A.-L. Do*

1. **Heads or tails? Fitting growing networks' degree distributions to empirical data** *Sara Cuenda*
2. **Testing time series irreversibility using complex network methods** *Jonathan F. Donges*
3. **Effective trapping of random walks in heterogeneous networks** *Byungnam Kahng*
4. **Oscillatory networks with time-delayed pulsatile coupling** *Vladimir Klinshov*
5. **Dynamical robustness of complex oscillator networks** *Gouhei Tanaka*

14.50–16.30 **CT2: Pattern formation and dynamics**
Room 2 *Chair: K. Showalter*

1. **Emergence of spatiotemporal dislocation chains in drifting patterns** *Monica A. Garcia-Nustes*
2. **Oscillatory Turing patterns in network-organized reaction-diffusion systems** *Shigefumi Hata*
3. **On the mechanisms for formation of segmented waves in active media** *Maria Borina*
4. **Patterns in active media caused by diffusion instability** *Andrey A. Polezhaev*
5. **Induced anisotropy in a pattern-forming reaction-diffusion system: Theory and experiments** *Jacobo Guiu-Souto*

14.50–16.30 **CT3: Social networks**
Room 3 *Chair: H. Chaté*

1. **Network analysis and urban bus flow in Madrid city** *Mary Luz Mouronte*
2. **The physics of information transmission in complex networks** *M. S. Baptista*
3. **What is a leader of opinion formation in bounded confidence models?** *Hector Alfonso Juarez*
4. **Strategies for the diffusion of behaviors in social networks** *Felipe Montes*
5. **Maintaining stable distribution in evolving supply-demand networks** *Nicolás Rubido*

14.50–16.30 **CT4: Neural dynamics**
Room 4 *Chair: I. Fischer*

1. **Spontaneous segregation of excitation and inhibition in a system of coupled cortical columns** *Daniel Malagarriga Guasch*
2. **Critical slowing down and decrease in resilience of neuronal networks precede transition to epileptic seizures in vitro.** *Premysl Jiruska*
3. **Bistability in neuronal firing induced by the network correlation feedback** *Victor Kazantsev*
4. **The mechanism of stochastic amplification explain fluctuations in the cortex** *Miguel A. Muñoz*
5. **Anatomo-functional organization in brain networks** *Jose Angel Pineda-Pardo*

14.50–16.30 **CT5: Transport phenomena**
Room 5 *Chair: B. Mehlig*

1. **Polygonal billiards: Spectrum and transport** *Roberto Artuso*
2. **Temperature resistant optimal ratchet transport** *Marcus Werner Beims*
3. **Mathematical model of self-organizing and adaptable intracellular transport network** *Konstantin Novikov*
4. **Noise induced phase transitions and coupled Brownian motors: Non standard hysteretic cycles** *Horacio S. Wio*
5. **From the physics of interacting polymers to optimizing routes on the London underground** *Chi Ho Yeung*

16.30–17.00 **Coffee break**

CT6: Synchronization 17.00–18.40
Chair: A. Diaz-Guilera Room 1

1. **Generalized synchronization of coupled nearly-identical dynamical systems** *Suman Acharyya*
2. **Collective almost synchronisation in complex networks** *M. S. Baptista*
3. **Synchronization and self-organization in multifrequency oscillator communities** *Maxim Komarov*
4. **Chaotic synchronization on scale-free hypernetworks** *Andrzej Krawiecki*
5. **Resilience of synchronization against topological changes in resonant and nonresonant coupled oscillators** *Jordi Zamora-Munt*

CT7: Methods in nonlinear dynamics 17.00–18.40
Chair: A. Politi Room 2

1. **Fluctuations in driven polymer translocation** *Johan L.A. Dubbeldam*
2. **Causality detection for short-term data** *Huanfei Ma*
3. **Theory of heteroclinic computation** *Fabio Schittler Neves*
4. **Granger causality in high-dimensional systems using restricted vector autoregressive models** *Elsa Siggiridou*
5. **Inference of time-evolving structural and functional relationships from networks of interacting oscillators** *Tomislav Stankovski*

CT8: Delayed systems 17.00–18.40
Chair: K. Pyragas Room 3

1. **Stochastic delay equations: Numerical methods for biophysical models** *Harish S. Bhat*
2. **Spectrum and amplitude equations for scalar delay-differential equations with large delay** *Leonhard Luecken*
3. **Reservoir Computing with a single nonlinear node subject to multiple delay feedbacks** *Silvia Ortín*
4. **Synchronization of neuronal complex networks in the presence of delayed interactions** *Toni Perez*
5. **CANCELLED.** ~~**Frequency discontinuity in the globally coupled oscillators with delay**~~ *Nirmal Punetha*

CT9: Fluids and granular media 17.00–18.40
Chair: S. Residori Room 4

1. **Model of a two-dimensional extended chaotic system: Evidence of diffusing dissipative solitons** *Orazio Descalzi*
2. **Nonlinear dynamics in experimental devices with compressed/expanded surfactant monolayers** *Maria Higuera*
3. **Photoisomerization front propagation in dye doped liquid crystal submitted to a Gaussian forcing** *Vincent Odent*
4. **New standing solitary waves in water** *Jean Rajchenbach*
5. **Shear induced alignment of elongated macroscopic particles** *Balázs Szabó*

CT10: Quantum and hamiltonian systems 17.00–18.40
Chair: A. Jorba Room 5

1. **Information and energy exchange in multidimensional chaotic Hamiltonian systems** *Chris Antonopoulos*
2. **Quantum dynamics: From coarse graining to a tower of scales via multiresolution** *Antonina N Fedorova*
3. **Experimental observation of resonance assisted tunneling in systems with a mixed phase space** *Stefan Gehler*
4. **Quantization of the strongly chaotic billiards near cosmological singularities of the gravitational field** *Michael Koehn*
5. **Comparison of Newtonian and relativistic dynamical predictions for low-speed and low-speed weak-gravity systems** *Boon Leong Lan*

9.00–9.45 **PT3: Plenary talk** *Chair: A. Pisarchik*
Room 1 **Quantifying gene-circuit dynamics at the single-cell level** *Jordi García-Ojalvo*

9.45–10.30 **PT4: Plenary talk** *Chair: A. Pisarchik*
Room 1 **Evolution on genotype networks leads to phenotypic entrapment** *Susanna C. Manrubia*

10.30–11.00 **Coffee break**

11.00–13.00 **MS6: Collective behavior in networks of oscillators**
Room 1 *Organizers: R. Toenjes and A.Torcini*
Chair: A. Torcini

1. **Extensive chaos and coherent dynamics in sparse networks** *Simona Olmi*
2. **Synchronization transition in sparse random networks of identical phase oscillators** *Ralf Toenjes*
3. **Nonuniversal transitions to synchrony in globally coupled phase oscillators** *Oleh Omel'chenko*
4. **Pulse coupling versus diffusive coupling in neural networks** *Antonio Politi*

11.00–13.00 **MS7: Localized structures of light in dissipative media I**
Room 2 *Organizers: M. Tlidi, K. Staliunas and K. Panajotov*
Chair: M. Tlidi, K. Staliunas and K. Panajotov

1. **Delay induced instabilities of localized structures of light in optical systems** *Andrei G Vladimirov*
2. **Spatiotemporal chaotic localized state in liquid crystal light valve experiments with optical feedback.** *Marcel Clerc*
3. **Spatial patterns and cavity solitons in spatially rocked nonlinear optical systems** *Germán J. de Valcárcel*
4. **Optical vortex self-assembly in liquid crystal media** *Stefania Residori*

11.00–13.00 **MS8: Nonlinear dynamics in lasers: Fundamental Issues and Novel Applications II**
Room 3 *Organizers: K. Lüdge and C. Masoller*
Chair: C. Masoller

1. **Utilizing semiconductor laser dynamics for photonic information processing** *Ingo Fischer*
2. **Two-mode dynamics of semiconductor lasers induced by optical injection and feedback** *Krassimir Panajotov*
3. **Nonlinear dynamics of quantum dot lasers under optical injection and feedback** *Eckehard Schöll*
4. **Coherence resonance in quantum-dot lasers with optical perturbations** *Kathy Lüdge*

11.00–13.00 **MS9: Complex dynamics and applications in cardiac electrophysiology**
Room 4 *Organizers: I. R. Cantalapiedra and J. Bragard*
Chair: J. Bragard

1. **Recent advances in mathematical modelling of cardiac tissue: A fractional step forward.** *Alfonso Bueno-Orovio*
2. **Defibrillation mechanisms on a one-dimensional ring of cardiac tissue** *Jean R. Bragard*
3. **Alternans due to refractoriness in SR Ca release dynamics** *Inmaculada R Cantalapiedra*
4. **Propagation of electrical activity in cardiac tissue; Experiment and theoretical validations for the study of spiral waves in the heart.** *Flavio H Fenton*

11.00–13.00 **MS10: Dynamics of nonspherical particles in turbulent flows**
Room 5 *Organizers: M. Wilkinson and B. Mehlig*
Chair: M. Wilkinson and B. Mehlig

1. **Tumbling rates in turbulent and random flows** *Kristian Gustavsson*
2. **Spherical and triangular Ornstein-Uhlenbeck processes** *Michael Wilkinson*
3. **Orientation statistics of elongated particles in turbulent flows.** *Alain Pumir*
4. **Orientation of axisymmetric particles in random flow** *Dario Vincenzi*

Lunch break 13.00–14.00

MS11: Emergent dynamics in coupled oscillators 14.00–16.00
Organizers: O. Omel'chenko and E. A. Martens Room 1
Chair: O. Omel'chenko and E. A. Martens

1. **When nonlocal coupling between oscillators becomes stronger: Patched synchrony or Multi-chimera states** *Iryna Omelchenko*
2. **The Kuramoto model with distributed shear** *Diego Pazó*
3. **Chimera States - how mythological monsters from mathematics arise in the real world** *Erik A. Martens*
4. **Synchronization and dynamical differentiation in small networks of chaotic electrochemical oscillators** *Istvan Z. Kiss*

MS12: Collective dynamics in living systems 14.00–16.00
Organizers: D. G. Míguez and R. Guantes Room 2
Chair: D. G. Míguez and R. Guantes

1. **Forces and waves during tissue growth** *Xavier Trepat*
2. **Collective animal behavior** *Gonzalo de Polavieja*
3. **Effects of coupling on sensory hair bundles** *Kai Dierkes*
4. **Regulation of neuronal differentiation at the neurogenic wavefront** *Saúl Ares*

MS13: Spatio-temporal vegetation patterns in ecosystems 14.00–16.00
Organizers: M. Tlidi and M. Clerc Room 3
Chair: M. Tlidi and M. Clerc

1. **Bistability in savanna/forest systems** *Roberto André Kraenkel*
2. **A quantitative theory of vegetation patterns in arid landscapes** *Mustapha Tlidi*
3. **Recent remote-sensing observations shed new light on broad scale vegetation patterns in drylands and raise new challenges for self-organization models** *Pierre Couteron*
4. **Strong interaction between plants induces circular barren patches: fairy circles** *Cristian Fernandez-Oto*

MS14: Quantum-chaotic dynamics: Theory and experiment 14.00–16.00
Organizers: I. Dana Room 4
Chair: S. Wimberger

1. **News from the (quantum) kicked rotor** *Sandro Wimberger*
2. **(Quantum) chaos, disorder, and ultracold atoms** *Jean Claude Garreau*
3. **Kicked rotor dynamics as a test system for Bose-Einstein condensate dynamical depletion** *Simon A. Gardiner*
4. **Staggered ladder quasienergy spectra for generic quasimomentum** *Itzhack Dana*

MS15: Molecules in motion through phase space bottlenecks 14.00–16.00
Organizers: R. M. Benito and F. Borondo Room 5
Chair: F. Borondo

1. **Detecting and analyzing methods of normally hyperbolic invariant manifolds** *Hiroshi Teramoto*
2. **Stochastic transition states and reaction barriers** *Thomas Bartsch*
3. **Including roaming trajectories within the TST fold** *Rigoberto Hernández*
4. **Normal forms for the dynamics of a laser-driven chemical reaction** *Àngel Jorba*

Poster and wine session 16.00–18.40

9.00–9.45 **PT5: Plenary talk** *Chair: D. Papo*
Room 1 **A new metrics for the economic complexity of countries and products** *Luciano Pietronero*

9.45–10.30 **PT6: Plenary talk** *Chair: D. Papo*
Room 1 **Model studies of electron transfer and conduction mediated by solitons in 1D and 2D crystal lattices** *Manuel G. Velarde*

10.30–11.00 **Coffee break**

11.00–13.00 **MS16: Control of synchronization in delay-coupled networks**
Room 1 *Organizers: E. Schöll and A. Zakharova*
Chair: E. Schöll

1. **Generalized synchronization properties of delay-coupled semiconductor lasers** *Ingo Fischer*
2. **Symmetry-breaking oscillation death in nonlinear oscillators with time-delayed coupling** *Anna Zakharova*
3. **Patterns of synchrony and death in networks with time delays** *Fatihcan M. Atay*
4. **Control of synchronization patterns in neural-like Boolean networks** *David P. Rosin*

11.00–13.00 **MS17: Localized structures of light in dissipative media II**
Room 2 *Organizers: M. Tlidi, K. Staliunas and K. Panajotov*
Chair: M. Tlidi, K. Staliunas and K. Panajotov

1. **Spontaneous spatial structures in cold atoms due to opto-mechanical coupling** *William Firth*
2. **Strong non-local coupling stabilizes localized structures** *Daniel Escaff*
3. **Towards temporal cavity solitons in semiconductor ring lasers** *Stephane Barland*
4. **Slowly evolving vector solitons in mode locked fibre lasers** *Sergey V. Sergeyev*

11.00–13.00 **MS18: Longwave and multiscale pattern formation**
Room 3 *Organizers: A. Nepomnyashchy and S. Shklyaev*
Chair: A. Nepomnyashchy

1. **Instabilities of perfect periodic large-scale wavy patterns** *Sergey Shklyaev*
2. **Pattern formation in horizontally vibrated rectangular containers** *Jose M. Vega*
3. **Long-wave description of the dynamics of evaporative pattern deposition** *Uwe Thiele*
4. **Pattern formation in drying thin liquid films** *Pierre Colinet*

11.00–13.00 **MS19: Interacting populations on social and ecological networks**
Room 4 *Organizers: R. M. Benito and J. C. Losada*
Chair: R. M. Benito

1. **Modeling bipartite networks with nestedness** *Javier Galeano*
2. **Monitoring Twitter. Tools for social graph visualization and automatic text classification** *Juan Pablo Cárdenas*
3. **Efficiency of human activity on information spreading on Twitter** *Alfredo J Morales*
4. **Meritocracy in the age of networks** *Javier Borondo*

11.00–13.00 **MS20: Dissipative solitons**
Room 5 *Organizers: O. Descalzi*
Chair: O. Descalzi

1. **Rare transitions in the carbon monoxide oxidation on Palladium(111) in ultra-high-vacuum conditions** *Jaime E Cisternas*
2. **Traveling convectons in binary mixtures** *Isabel Mercader*
3. **Explosive dissipative solitons** *Carlos Cartes*
4. **Localized hexagonal patches of spikes on a layer of ferrofluid** *Reinhard Richter*

13.00–14.00 **Lunch break**

PT7: Plenary talk *Chair: J.M. Buldú*	14.00–14.45
The Fragility of Interdependency: Coupled Networks & Switching Phenomena *H. Eugene Stanley*	Room 1
PT8: Plenary talk *Chair: J.M. Buldú*	14.45–15.30
Title TBA *Mitchell J. Feigenbaum*	Room 1
Coffee break	15.30–16.00
Excursion and conference dinner	16.00–24.00

9.00–9.45 **PT9: Plenary talk** *Chair: J. A. Almendral*
Room 1 **Mechanism of dissipation in turbulent quantum fluids at ultra low temperatures** *Itamar Procaccia*

9.45–10.30 **PT10: Plenary talk** *Chair: J. A. Almendral*
Room 1 **Distinguishing signatures of determinism and stochasticity in spiking complex systems** *Cristina Masoller*

10.30–11.00 **Coffee break**

11.00–13.00 **MS21: Dynamics of multistable systems**
Room 1 *Organizers: A. Pisarchik*
Chair: A. Pisarchik and R. Jaimes-Reátegui

1. **Study of multistate intermittency and extreme pulses by low-pass filtered noise in a fiber laser** *Rider Jaimes-Reátegui*
2. **Noise-induced bistability and on-off intermittency in mutually coupled semiconductor lasers** *Alexander N. Pisarchik*
3. **Inhomogeneous stationary and oscillatory regimes in coupled chaotic oscillators** *Evgeny Volkov*
4. **Extreme multistability and synchronization in coupled systems** *Ulrike Feudel*

11.00–13.00 **MS22: Stochastic population dynamics**
Room 2 *Organizers: B. Mehlig*
Chair: B. Mehlig

1. **Metapopulation dynamics on the brink of extinction** *Bernhard Mehlig*
2. **Large velocity fluctuations of stochastic invasion fronts** *Baruch Meerson*
3. **Fluctuations as a source of population stability** *Alex Kamenev*
4. **Stochastic evolutionary game dynamics** *Arne Traulsen*

11.00–13.00 **MS23: Time series and causality networks**
Room 3 *Organizers: M. Small and D. Kugiumtzis*
Chair: M. Small and D. Kugiumtzis

1. **Nonlinear Granger causality: Guidelines for multivariate analysis** *Cees Diks*
2. **Investigating causal relationships – application to financial time series** *Angeliki Papana*
3. **Quantifying network interaction and synchrony in multi-electrode recordings** *Michael Small*
4. **EEG Analysis of information flow during music performance** *Xiaogeng Wan*

11.00–13.00 **MS24: Temporal cavity solitons and fronts in photonic crystal fiber resonators**
Room 4 *Organizers: M. Tlidi and A. Vladimirov*
Chair: M. Tlidi and A. Vladimirov

1. **Femtosecond pulse compression in Non linear photonic crystal fiber** *Lynda Cherbi*
2. **Dynamics of supercontinuum generated in photonic crystal fiber ring configurations** *Nicolas Y. Joly*
3. **Linear wave packet structure and rogues waves statistics in nonlinear Schrödinger equation** *Saliya Coulibaly*
4. **Dark temporal cavity solitons in photonic crystal fiber resonators** *Mustapha Tlidi*

11.00–13.00 **MS25: Extreme events**
Room 5 *Organizers: Dynamics Days*
Chair: A. Pumir

1. **Rare event prediction in stochastic systems with multiple time scales** *Christoffer R. Heckman*
2. **Extreme fluctuations and long-time memory of large scale wind power production** *Oliver Kamps*
3. **CANCELLED.** **~~Extreme relative velocities of heavy particles in turbulent flow~~** *Ewe-Wei Saw*
4. **Damped wind-driven rogue waves** *Constance Marie Schober*

Lunch break 13.00–14.00

PT11: Plenary talk *Chair: I. Leyva* 14.00–14.45
Taming complexity: Controlling networks *Albert-Lázló Barabási* Room 1

CT11: Networks II 14.50–16.30
Chair: A.-L. Barabási Room 1

1. **Network vulnerability to extreme events** *Ravindra E. Amritkar*
2. **The architecture of biologically inspired adaptive transport networks** *Johannes Gräwer*
3. **Analyzing the interplay among the layers of a multiplex on the overall diffusion dynamics** *Nikos E Kouvaris*
4. **Hierarchies behind failure of heterogeneous media** *C. Felipe Saraiva Pinheiro*
5. **Sisyphus effect in neural networks with spike timing dependent plasticity** *Alessandro Torcini*

CT12: Dynamics of coupled oscillators 14.50–16.30
Chair: C. Masoller Room 2

1. **Phase dynamics of limit-cycle oscillators subjected to strong perturbations** *Wataru Kurebayashi*
2. **Sequential switching activity in ensembles of excitatory and inhibitory coupled oscillators** *Grigory Osipov*
3. **Mean field and mean ensemble frequencies of a system of coupled oscillators** *Spase Petkoski*
4. **Complex dynamics and invariant tori in low-dimensional ensembles of oscillators.** *Ludmila Vladimirovna Turukina*
5. **Emerging of new classical structures in coupled chaotic microcavities** *Jung-Wan Ryu*

CT13: Nonlinear optics and lasers 14.50–16.30
Chair: C. Mirasso Room 3

1. **Characterizing the dynamics of a semiconductor laser with optical feedback and modulation using ordinal analysis** *Andrés Aragoneses Aguado*
2. **Distinguishing deterministic and noise-driven power-dropout events in semiconductor lasers with delayed feedback** *Konstantin Hicke*
3. **Strong and weak chaos in networks of semiconductor lasers with time-delayed couplings** *Thomas Jüngling*
4. **Experimental characterization of laser droplet generation dynamics** *Alexander Kuznetsov*
5. **Chaotic canard explosions in a slow-fast nonlinear optomechanical oscillator** *Francesco Marino*

CT14: Spatio-temporal dynamics 14.50–16.30
Chair: M.G. Velarde Room 4

1. **Effects of nonlinear diffusion on biological population spatial patterns** *Celia Anteneodo*
2. **Spatial constraints in the distribution of linguistic diversity** *Jose A. Capitan*
3. **Spatial correlations in nonequilibrium reaction-diffusion problems by the Gillespie algorithm** *Jose M. Ortiz de Zárate*
4. **On the stability of kink-like and soliton-like solutions of the generalized convection-reaction-diffusion equation** *Vsevolod Vladimirov*
5. **Selection of spiral waves in excitable media with a phase wave at the wave back** *Vladimir Zykov*

CT15: Biophysics and biomedicine 14.50–16.30
Chair: S. Manrubia Room 5

1. **Biophysical origins of the second pitch-shift effects** *Florian Gomez*
2. **Evolutionary dynamics of populations with genotype-phenotype map** *Esther Ibañez*
3. **Heart rate variability analysis and its effectiveness in differentiate diseases** *Laurita dos Santos*

4. **Detecting nonlinear dynamics in human heart rate variability by deterministic nonlinear prediction** *Nina V. Sviridova*
5. **The interaction of disease spread and information propagation in metapopulation networks** *Bing Wang*

16.30–17.00 **Coffee break**

17.00–18.40 **CT16: Chaos**
Room 1 *Chair: M.J. Feigenbaum*

1. **New theory of intermittency. Effect of noise on the length probability density** *Ezequiel del Rio*
2. **Universal scaling of Lyapunov-exponent fluctuations in space-time chaos** *Juan Manuel López*
3. **From mode competition to polarization chaos in free-running VCSELs** *Martin Virte*
4. **Stability index for riddled basins of attraction** *Ummu Atiqah Mohd Roslan*
5. **Universality in weak chaos** *Roberto Venegeroles*

17.00–18.40 **CT17: Stochastics processes**
Room 2 *Chair: J. García-Ojalvo*

1. **Stochastic crater at the nanoscale: experimental evidences** *Cédric Barroo*
2. **A binomial stochastic simulated study of mutualism** *Javier Garcia-Algarra*
3. **Patterns and survival of competitive Levy and Brownian walkers** *Emilio Hernández-García*
4. **Noise assisted morphing of memory and logic function** *Vivek Kohar*
5. **Effects of noise on the Shapiro steps** *Jasmina Tekic*

17.00–18.40 **CT18: Biological and ecological systems**
Room 3 *Chair: U. Feudel*

1. **Micro and macro-scale models of population dynamics in a cell culture** *M. Gokhan Habiboglu*
2. **Complex communication between social whales** *Sarah Hallerberg*
3. **A functional network representation of the DNA** *Shambhavi Srivastava*
4. **Physical properties of the phloem constrain size and shape of leaves** *Henrik Ronellenfitsch*
5. **Spatio-temporal dynamics of ecosystems for acorn masting and ecological management** *Tiejun Zhao*

17.00–18.40 **CT19: Statistical physics**
Room 4 *Chair: L. Pietronero*

1. **Criticality in dynamic arrest: Correspondence between glasses and traffic** *A. S. de Wijn*
2. **Complex Systems with an H-Theorem** *Ricardo Lopez-Ruiz*
3. **Nonequilibrium phase transitions caused by dynamical traps** *Ihor Lubashevsky*
4. **The mechanics of structured particles and why it is important** *Vyacheslav Michailovich Somsikov*
5. **A tower of scales in plasma modeling: Order, disorder, fusion** *Michael G Zeitlin*

17.00–18.40 **CT20: Fluid dynamics**
Room 5 *Chair: I. Procaccia*

1. **CANCELLED. ~~Extreme events in turbulent relative dispersion~~** *Jérémie Bec*
2. **Numerical simulation of hypersonic real gas flow** *Stanislav Viktorovich Kirilovskiy*
3. **Hydrodynamic instability in two orbiting particles levitated in a vibrated liquid** *Liang Liao*
4. **Limit cycle behavior in the statistical description of turbulent Rayleigh-Bénard convection** *Johannes Lülff*
5. **Numerical study for convection near the stability threshold in a finite homogeneously heated fluid layer.** *Olga Mazhorova*

PT12: Plenary talk *Chair: E. Pereda* 9.00–9.45
Meso-scale structures induce characteristic instabilities in networks of coupled dynamical systems *Anne Ly Do* Room 1

PT13: Plenary talk *Chair: E. Pereda* 9.45–10.30
Time as coding space for information processing in the cerebral cortex *Wolf Singer* Room 1

Coffee break 10.30–11.00

MS26: Complex networks in climate dynamics 11.00–13.00
Organizers: E. Hernández-García Room 1
Chair: E. Hernández-García

1. **Network of networks and the climate system** *Juergen Kurths*
2. **Interaction network based early warning indicators for the Atlantic MOC collapse** *Henk A. Dijkstra*
3. **Coupling within and across multiple scales of climate dynamics** *Milan Paluš*
4. **No signs of lag-time effects in the connectivity of climate networks constructed with surface temperature anomalies** *Giulio Tirabassi*

MS27: Multiplex time-varying and evolutive complex networks 11.00–13.00
Organizers: R. Criado and M. Romance Room 2
Chair: M. Romance and R. Criado

1. **Emergence of network features from multiplexity** *Jesus Gomez-Gardenes*
2. **Stability of boolean multilevel networks** *Yamir Moreno*
3. **Time-varying directed networks from EEG signals** *Fabrizio de Vico Fallani*
4. **Multiple opinion leaders in a multi-layer social network** *Rosa María Benito*

MS28: Control of nonlinear systems 11.00–13.00
Organizers: Dynamics Days Room 3
Chair: A. Pisarchik

1. **Application of act and wait control to oscillatory network desynchronization** *Irmantas Ratas*
2. **Granular fronts in parametrically forced shallow granular layers** *Claudio Falcón*
3. **Beyond the odd number limitation: Control matrix design for time delayed-feedback control algorithm** *Kestutis Pyragas*
4. **Optimal control of nonlinear dynamics: Quantum-classical correspondence** *Toshiya Takami*

MS29: The critical role of dynamics in hearing 11.00–13.00
Organizers: J. Cartwright and R. Stoop Room 4
Chair: J. Cartwright and R. Stoop

1. **Stochastic resonance in a full model of the peripheral auditory pathway** *Stefan Martignoli*
2. **From physiology to psychophysics to electronics: The role of nonlinear dynamics in pitch perception** *Diego Luis Gonzalez*
3. **Dynamics of otoacoustic emissions in lizards** *Oreste Piro*
4. **Fish: how do they hear; and how do they make their ears?** *Julyan Cartwright*

MS30: From the neuronal systems to the brain 11.00–13.00
Organizers: E. Pereda and F. Maestú Room 5
Chair: E. Pereda

1. **Causal estimates in the presence of mixed and colored noise** *Guido Nolte*
2. **Shadows of early development on brain's functional network: An exploratory study on complex brain networks in preschool years (3-4 years)** *Joydeep Bhattacharya*
3. **Classification of ADHD patients from EEG patterns of functional connectivity using Bayesian networks** *Ernesto Pereda*
4. **Anticipated synchronization in cortical circuits** *Claudio R Mirasso*

Closing 13.00–13.30

Lunch break 13.30–14.30

POSTER LIST

P1 **Normal form transformation explains effect of noise near Hopf bifurcation** *Matthew James Aburn*
P2 **Chaotic dynamics in multidimensional transition states** *Ali Allahem*
P3 **Parameter estimation in nonlinear models** *Leandro Martin Alonso*
P4 **Nonlinear oscillations in birdsong** *Leandro Martin Alonso*
P5 **Dynamical features of interictal spikes in the human brain undergoing anesthesia** *Leandro Martin Alonso*
P6 **Stochastic simulation of people moving in confined spaces** *Everaldo Arashiro*
P7 **Aging and memory maintenance: Tracking the evolution of functional networks** *Pedro Ariza*
P8 **Collective almost synchronisation in complex networks** *M. S. Baptista*
P9 **From mono- to bi- modal self-sustained periodic oscillations: Nanoscale catalytic NO2 reduction** *Cédric Barroo*
P10 **Contemporary tools for reducing the model error in weather and climate forecasting models** *Lasko Basnarkov*
P11 **Controlling the system with hyperbolic attractor** *Sergey Tichonovich Belyakin*
P12 **Determining functional and physical connectivity in complex time-series** *Ezequiel Bianco-Martinez*
P13 **Intermingled basins in coupled Lorenz systems** *Sabrina Camargo*
P14 **Fermi acceleration in the annular billiard under magnetic field action** *Bruno Castaldi*
P15 **Experimental study of firing death in a network of chaotic FitzHugh-Nagumo neurons** *Marzena Ciszak*
P16 **Phase noise performance of double-loop optoelectronic microwave oscillators** *Pere Colet*
P17 **High-speed key exchange using chaotic systems** *Pere Colet*
P18 **Synchronization and Quantum Correlations in Harmonic Networks** *Pere Colet*
P19 **Adler synchronization of spatial laser solitons pinned by defects** *Pere Colet*
P20 **Tuning the period of square-wave oscillations in two delay coupled systems with delay feedback** *Pere Colet*
P21 **Longitudinal and large scale characterization of freely self-organized cultured neural networks** *Daniel de Santos-Sierra*
P22 **Towards a biophysical description of contractile pulses of amnioserosa cells during dorsal closure** *Kai Dierkes*
P23 **Multivariate extensions of recurrence networks: Geometric signatures of coupled nonlinear systems** *Jonathan F. Donges*
P24 **Predator-prey systems with seasonal migration** *John Gerard Donohue*
P25 **Scaling exponents of rough surfaces generated by damage spreading in the Ising model** *Felipe Aguiar Severino dos Santos*
P26 **Implementation of an optoelectronics logic gate dynamically flexible using a laser fiber, numerical study** *Juan Hugo García-Lopez*
P27 **Formation of two-kink solitons due to the presence of a localized external force** *Monica A. Garcia-Nustes*
P28 **Dynamics of the early stage of pattern formation in the ferrocyanide-iodate-sulfite reaction-diffusion system: branching and budding** *Vilmos Gáspár*
P29 **Building a triple agent model for financial markets** *Elena Green*
P30 **Phase diagram of a cyclic predator-prey model with neutral-pairs exchange** *Nara Guisoni*
P31 **Interfacial properties in a discrete model for tumor growth** *Nara Guisoni*
P32 **A quantitative model for tissue homeostasis** *Nara Guisoni*
P33 **Chimera states in networks of excitable elements** *Johanne Hizanidis*
P34 **CANCELLED.** **~~The nature of weak generalized synchronization in chaotically driven maps~~** *Haider Hasan Jafri*
P35 **Preferential growth of weighted mutualistic networks** *Manuel Jimenez-Martin*
P36 **Synchronization and spatial coherence of neuronal populations increase the probability of seizure termination.** *Premysl Jiruska*
P37 **Emergence of epidemics in rapidly varying networks** *Vivek Kohar*
P38 **Pattern formation and control in networks of bistable elements** *Nikos E Kouvaris*
P39 **Chimera states for repulsively coupled oscillators** *Volodymyr Maistrenko*

P40 Consistency, complex networks and mild cognitive impairment *Johann Heinz Martínez Huartos*

P41 Decision support systems towards the intelligent analysis and classification of cerebral inflammation as measured with multi-parametric Magnetic Resonance *Ana Belén Martín-Recuero*

P42 Dynamics of the individual properties and the collective behavior in living matter *Shiraishi Masashi*

P43 Extreme intensity pulses in a semiconductor laser with a short external cavity *Cristina Masoller*

P44 The role of diffusion and shear diversity in collective synchronization *Ernest Montbrió*

P45 Infinite modal map and on-off intermittency *Masaki Nakagawa*

P46 Complex network analysis of connectivity patterns from MEG data of epileptic patients *Guiomar Niso*

P47 Analytical properties of autonomous systems controlled by extended time-delay feedback in the presence of a small time delay mismatch *Viktor Novičenko*

P48 Front pinning induced by spatial inhomogeneous forcing in a Fabry-Pérot Kerr cavity with negative diffraction *Vincent Odent*

P49 Exact analysis of stochastic bifurcation in ensembles of globally coupled limit cycle oscillators with multiplicative noise *Keiji Okumura*

P50 Causality Information planes: a new tool for dynamical systems *Felipe Olivares*

P51 Exchange rate volatility and economic calendar announcements: Some causal calculations *Guillermo Ortega*

P52 Directed communication-through-coherence during synchronous transients *Agostina Palmigiano*

P53 Distinct bifurcation mechanisms for binary decision making in biological systems *Benjamin Pfeuty*

P54 Consistency through transient chaos *Antonio Javier Pons*

P55 Observation of star-shaped surface gravity waves. *Jean Rajchenbach*

P56 Computing chaotic eigenfunctions using localized wave functions over periodic orbits *Fabio Revuelta*

P57 Reaction rate calculation for dissipative systems using invariant manifolds *Fabio Revuelta*

P58 Inference in networks embedded in metric spaces *Victor Manuel Rodriguez Mendez*

P59 A study of spontaneous activity in modular neural networks made of neurons of different intrinsic dynamics *Antonio C. Roque*

P60 Networks of oceanic transport in the mediterranean *Enrico Ser Giacomi*

P61 Experimental implementation of maximally synchronizable graphs *Ricardo Sevilla*

P62 Review of cases of integrability in dynamics of low- and multidimensional rigid body in a nonconservative field *Maxim V. Shamolin*

P63 Synchronization of quasiperiodic oscillations by pulses action. *Nataliya Stankevich*

P64 Adaptive POD-based ROMs to approximate bifurcation diagrams *Filippo Terragni*

P65 The role of Pacific decadal oscillation in climate dynamics *Giulio Tirabassi*

P66 Multi-fractal relation in seismicity statistics: Data analysis of earthquakes around 3.11.2011 *Satoru Tsugawa*

P67 CANCELLED. ~~Chimera States with Multiple Coherent Regions~~ *Sangeeta Rani Ujjwal*

P68 Neural dynamics underlying spatio-temporal low-frequency fluctuations in the resting brain activity *Vesna Vuksanovic*

P69 Stochastic models for climate reconstructions *Johannes P Werner*

P70 Analysis of cerebral inflammation MRI data by means of complex networks *Massimiliano Zanin*

P71 The topological model for a qubit: Quantum states in the sheaf framework *Michael G Zeitlin*

P72 Periodic dynamics of intrinsically motivated learning *Arkady Zgonnikov*

P73 Human control of dynamical systems: Insights from virtual stick balancing *Arkady Zgonnikov*

P74 Global stability and local bifurcations in a two-fluid model for tokamak plasma *Delyan Atanasov Zhelyazov*

P75 Reconstruction of causality from short environmental time series *Heidelinde Röder*

P76 Collective Chaos and Chimera States in pulse-coupled neural networks *Simona Olmi*

ABSTRACTS

PT1: Plenary talk

Synchronization in populations of chemical oscillators: Quorum Sensing, phase clusters and chimeras

Kenneth Showalter

West Virginia University, Morgantown, USA; kshowalt@wvu.edu

We have studied large, heterogeneous populations of discrete chemical oscillators ($\sim$100,000) to characterize two different types of density-dependent transitions to synchronized behavior, a gradual Kuramoto synchronization and a sudden quorum sensing synchronization. We also describe the formation of phase clusters, where each cluster has the same frequency but is phase shifted with respect to other clusters, giving rise to a global signal that is more complex than that of the individual oscillators. Finally, we describe experimental and modeling studies of chimera states and their relation to other synchronization states in populations of coupled chemical oscillators.

MS1: Dynamical processes on complex networks

The study of propagation and evolutionary dynamical processes taking place on complex networks has recently attracted the interest of researchers belonging to a wide variety of fields. The reason is that the development of a common methodology in this context could hopefully allow analyzing dynamical behaviours on biological, technological or sociological systems from a general and more powerful perspective. From a dynamical point of view, two kinds of processes occurring on a network can be analyzed: (i) those that take place in static networks and therefore maintain the topology of the network, and (ii) those occurring in dynamic or evolving networks, where the number of nodes or their connections vary with time. In this mini symposium, we focus on recent relevant results obtained for both kinds of processes, paying special attention to its generality and applicability to real systems. The invited speakers will analyze a wide range of systems, from social to genotype networks, and will discuss the new challenges that this promising subject should face in the forthcoming years.

Organizers: *D. Gómez-Ullate and J. Aguirre*

Synchronization in contact networks of mobile oscillators

Albert Diaz-Guilera[1], *Oleguer Sagarra*[2] *and Luce Prignano*[3]

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I present some recent results obtained in our group about time dependent networks as formed by mobile agents that interact when they are within some range. Different types of dynamics have been implemented and different regimes are observed. Transitions between regimes are characterized by defining the appropriate control parameters.

Using Friends as Sensors to Detect Global-Scale Contagious Outbreaks

Manuel Garcia-Herranz[1], *Esteban Moro*[2], *Manuel Cebrian*[3], *Nicholas A Christakis*[4] *and James H Fowler*[5]

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[2]Universidad Carlos III de Madrid, Leganes, Spain; emoro@math.uc3m.es
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Recent research has focused on the monitoring of global-scale online data for improved detection of epidemics, mood patterns, movements in the stock market, political revolutions, box-office revenues, consumer behaviour and many other important phenomena. However, privacy considerations and the sheer scale of data available online are quickly making global monitoring infeasible, and existing methods do not take full advantage of local network structure to identify key nodes for monitoring. Here, we develop a model of the contagious spread of information in a global-scale, publicly-articulated social network and show that a simple method can yield not just early detection, but advance warning of contagious outbreaks. In this method, we randomly choose a small fraction of nodes in the network and then we randomly choose a "friend" of each node to include in a group for local monitoring. Using six months of data from most of the full Twittersphere, we show that this friend group is more central in the network and it helps us to detect viral outbreaks of the use of novel hashtags about 7 days earlier than we could with an equal-sized randomly chosen group. Moreover, the method actually works better than expected due to network structure alone because highly central actors are both more active and exhibit increased diversity in the information they transmit to others. These results suggest that local monitoring is not just more efficient, it is more effective, and it is possible that other contagious processes in global-scale networks may be similarly monitored.

Competition between complex networks: phenomenology and winning strategies

Jacobo Aguirre[1], *David Papo*[2] *and Javier M. Buldú*[3]

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[2]Center for Biomedical Technology (UPM), Madrid, Spain; papodav@gmail.com
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Competitive interactions represent a driving force behind evolution and natural selection in biological and sociological systems. For example, websites may compete over the same group of internauts, animals in an ecosystem may vie for resources, and firms in a market economy may compete over customers.
In the present study we derive general rules governing the competitive interactions between groups of agents organized in networks [1]. We show that the winner of the competition, and the time needed to prevail, essentially depend on the way a given network connects to its competitors and on its internal structure. Furthermore, we provide strategies through which competing networks can improve on their situation, and introduce a competition parameter Ω to assess the extent to which real networks optimize the outcome of their interaction.
The proposed approach is applicable to a wide range of social, biological, or technological systems that can be modeled as networks.

[1] J. Aguirre, D. Papo and J.M. Buldú. *Nature Physics* advance online publication 24 Feb 2013. DOI:10.1038/NPHYS2556

Search for optimal function in RNA populations evolving over networks of genotypes

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RNA molecules, through their dual identity as sequence and structure, are an appropriate experimental and theoretical model to study the genotype-phenotype map and evolutionary processes taking place in simple replicator populations. As RNA sequences mutate, they not only explore the genotype space, but also access new, possibly very different structures. Therefore, a population moves at the same time dynamically on the regular network formed by sequences and on the network formed by the structures. We assume that RNA secondary structure is a simple representation of the phenotype of the molecule, and we identify a given target structure as the one conferring optimal function to the population in a given environment, i.e., we apply a selective pressure. In this presentation, we review some well-known properties of the sequence-structure map, in particular the existence of common and rare structures. Then, we relate these properties with the number of replication events that an initially random population of sequences needs in order to find that structure through mutation and selection. For common structures, this search process turns out to be much faster than for rare structures. Furthermore, search and mutation processes are more efficient in a wider range of mutation rates for common structures, thus indicating that evolvability of RNA populations is not simply determined by abundance. We also find dependence on the number of base pairs forming the structure and the nucleotide content. As a result, although the population moves on the simple network of sequences, the sequence-structure map and the complex phenotype space are fundamental to understand the evolution of the population. [*]

Centro de Astrobiologia (CSIC-INTA), Torrejón de Ardoz, Spain.

MS2: Characterizing neuronal interactions and synchronization in the brain dysfunction epilepsy

The disease epilepsy is associated with excessive synchronization of networks of neurons. For systems studied in physics it was already observed by Christiaan Huygens that synchronization is caused by interactions between dynamical systems. Evidently interactions between neurons are the basis of any function of the brain, and synchronization is considered essential for higher cognitive functions. However, we are far from fully understanding what alterations in neuronal interactions underlie the hypersynchronization found in the brain dysfunction epilepsy. We address this problem by analysing signals from the epileptic brain recorded at different spatial scales. At the largest scale we analyse electroencephalographic (EEG) recordings which integrate the activity of millions of neurons from volumes of several cubic centimetres. At the smallest scale we analyse the firing activity of individual neurons. On this microscopic scale we aim to identify the rules governing the circuit dynamics in epilepsy. On the macroscopic EEG scale we discuss how nonlinear measures for synchronization can help to localize the seizure generating brain area from the seizure-free interval. Here, we study the influence of an important confounding factor: the nonstationarity of the dynamics. We use causality measures to monitor the temporal evolution of brain connectivity in the course of epileptiform discharges. We analyze how Transcranial Magnetic Stimulation can alter neuronal interactions during these discharges and possibly terminate them.

Organizers: *R. G. Andrzejak*

Focusing outside the focus the causes of focal seizures

Guillermo José Ortega[1], *Rafael García de Sola*[2] *and Jesús Pastor*[3]

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The traditional treatment of drug-resistant temporal lobe epilepsy is in locating and removing the so called epileptic "focus", the cortical area responsible of the epileptic seizures. However, even in cases where the focus has been correctly located and eliminated, post-operative seizures are still present. In this talk we will present some new results based on the nonlinear time series analysis of neurophysiological records from epilepsy patients. Our results show that the underlying dynamic of synchronization/desynchronization between several cortical areas could be the key element to be considered. Surgery strategies should therefore be aimed to destroy the synchronizability properties of the limbic network instead of focusing in removing the epileptogenic region.

Dynamic markers of epileptogenesis and seizures at multiple scales

Liset Menendez de la Prida

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Epilepsy is a dynamic disease associated with excessive synchronization of neuronal networks. Recent evidence shows that epileptiform activities result from complex dynamic interactions between neuronal networks characterized by firing heterogeneity and dynamical evolution of synchronization. Here, I will discuss our recent data aimed to identify the rules governing circuit dynamics in temporal lobe epilepsy, obtained with a combination of techniques including multi-site recordings and single-cell electrophysiology. We will focus on different forms of activity, including several types of oscillations that can be used as dynamic markers of epileptogenesis and ictogenesis.

Brain connectivity during epileptiform discharges is altered by TMS

Dimitris Kugiumtzis[1] *and Vasilios K. Kimiskidis*[2]

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The connectivity structure of brain areas is believed to change under pathological brain conditions, such as epileptic seizures. Here we study interictal discharges and subclinical epileptic seizures, collectively termed epileptiform discharges (ED), and we examine the brain connectivity before, during and after ED [1]. The aim of the study is to investigate whether Transcranial Magnetic Stimulation (TMS) can alter the brain connectivity during ED and possibly terminate the ED. We attempt to monitor the brain connectivity from multi-channel electroencephalograms (EEG), and for this we employ a recently developed Granger causality measure called partial mutual information from mixed embedding (PMIME) [2, 3]. PMIME has the advantage to be able to detect direct causal effects in the presence of many inter-related variables. We first show the appropriateness of PMIME for the multi-channel EEG analysis comparing it with other known Granger causality measures (conditional Granger causality index and partial transfer entropy). In particular, by estimating the Granger causality measures on sliding EEG segments, we show that PMIME detects optimally the change of brain connectivity with the occurrence of ED. Then we present evidence from PMIME that the administration of repetitive TMS alters the brain connectivity and possibly terminates ED.

[1] V.K. Kimiskidis, D. Kugiumtzis, S. Papagiannopoulos and N. Vlaikidis. "Transcranial magnetic stimulation (TMS) modulates epileptiform discharges in patients with frontal lobe epilepsy: a preliminary EEG-TMS study". *International Journal of Neural Systems* **23(01)** 1250035 (2013).
[2] I. Vlachos and D. Kugiumtzis. "Non-uniform state space reconstruction and coupling detection". *Physical Review E* **82** 016207 (2010).
[3] D. Kugiumtzis. "Direct coupling information measure from non-uniform embedding". Submitted to Physical Review Letters (2013).

Electroencephalographic signals from seizure-generating brain areas: less randomness, more nonlinear-dependence, and more stationarity

Ralph Gregor Andrzejak[1], *Kaspar Schindler*[2] *and Christian Rummel*[3]

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We combine surrogate time series with a nonlinear prediction error, a nonlinear interdependence measure, and linear variability measures to derive tests for randomness, nonlinear-independence, and stationarity, respectively [1]. We apply these tests to intracranial electroencephalographic recordings (EEG) from patients with pharmaco-resistant focal-onset epilepsy. These EEG recordings were performed as part of the invasive phase of epilepsy diagnostics. The clinical purpose of these recordings was to delineate the brain areas to be surgically removed in the individual patients in order to achieve seizure control. This allowed us to define two distinct sets of signals: One set of signals recorded from brain areas where the first seizure related EEG signal changes were detected as judged by expert visual inspection ('focal EEG signals') and one set of signals recorded from brain areas that were not involved at seizure onset ('nonfocal EEG signals'). In our analysis, we restrict ourselves to recordings from the seizure-free interval. We will present the rejection probabilities of the different tests obtained for the focal and nonfocal signals. Furthermore, we will study the mutual dependence between the rejections of the different tests. Our results show that focal EEG signals are less random, more nonlinear-dependent, and more stationary compared to nonfocal EEG signals. In consequence, this analysis can help to distinguish focal and nonfocal signals and thereby help to localize brain areas where seizures originate without the necessity to observe actual seizure activity. The data, source code, and detailed results of this study can be found at http://sigan.upf.edu.

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MS3: Nonlinear dynamics in lasers: Fundamental Issues and Novel Applications I

Dynamics of single- and double-contact hybrid-cavity semiconductor lasers under fast frequency tuning by an intracavity filter

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Fast tunable lasers can find a number of applications, mainly in information acquisition systems. One example is tunable laser spectroscopy, or swept source Optical Coherence Tomography (OCT) [1] Swept-source OCT typically uses external cavity laser diodes frequency-swept by means of a tunable intracavity filter. Ring lasers have been used previously [2]; however, the recent development of a highly frequency selective, compact reflecting filter [1, 3] has allowed a simpler, more compact Fabry-Pérot construction to be used [1] and shows complex dynamics with strong asymmetry depending on the direction of tuning. Previously, we have used numerical modeling to relate the peculiarities of this dynamics to the laser parameters and investigate the roles of linewidth enhancement factor, tuning speed, and filer bandwidth [4]. In the talk, the analysis will be extended to present a more systematic view and also to consider reducing the tuning asymmetry, by using a multicontact laser with an intracavity saturable absorber (SA). We use the well-tested travelling wave laser model LasTiDom (see [4]). The structure simulated consists of an active semiconductor chip with, with or without an SA, with the outer facet reflecting and the inner facet (facing a passive cavity) with zero reflectance, a passive resonator, and a tunable reflector simulating the filter. The gain chip is assumed to be a MQW semiconductor laser amplifier; the parameters are largely taken from the literature, and the tuneable filter is modeled as in [4].

In a single-contact structure, as in [4], the laser dynamics under red tuning (from short to long wavelength) and a filter bandwidth exceeding the intermodal distance shows, with an increase in the sweeping speed, a bifurcation sequence including quasi-single-mode mode hopping, irregular chaotic dynamics, period doubled self mode locking, and period-one self mode locking. Under blue tuning, the dynamics is always irregular, the output power is lower, and the frequency tuning range shorter than under red tuning. This is due to unfavourable modal interaction during sweeping, quantified by the linewidth enhancement factor α_H. In a hypothetical structure with $\alpha_H = 0$, the tuning would be symmetrical as in [2, 3, 4].

It can be expected that in a laser with the SA, the opposite actions of self-phase modulation in gain and SA sections can cancel each other and lead to more symmetric tuning. Indeed with the SA included in the cavity, the laser always shows mode locked dynamics, fundamental or harmonic depending on pumping current, as can be expected. Qualitative asymmetry between red and blue tuning is thus removed, and the average power curve is somewhat more symmetric than in the single-cavity laser though complete removal of asymmetry has not yet been achieved.

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Oscillatory and excitable dynamics of dissipative solitons in optical cavities

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Dissipative solitons (DS) arise in a large variety of systems from a balance between nonlinearity and spatial coupling, and driving and dissipation. In optical cavities, DS (also known as cavity solitons) have been proposed as bits for all-optical memories [1], due to their spatial localization and bistable coexistence with the fundamental solution.

Beyond the steady state regime, DS can display a variety of dynamical regimes such as periodic oscillations, chaos, or excitability. Excitability mediated by DS [2], is different from the well-known dynamics of excitable media, whose behavior stems from the (local) excitability present in the system without spatial degrees of freedom. Excitability of DS is an emergent behavior, arising through the spatial interaction and not present locally.

DS interact through their tails which typically are oscillatory. Static DS interact anchor at a discrete set of distances [3]. Oscillatory LS are an example of non-punctual oscillators, i.e. oscillators with an internal structure. The interplay between the coupling and the internal structure is a general phenomenon not well understood. We study this by considering a prototypical model for a optical Kerr cavity [4]. When two oscillating DS are placed close together, the mutual interaction locks the DS to three different equilibrium distances and leads to the appearance of two limit cycles, one in phase and one in anti-phase. For the smaller distance, the coupling of the oscillations with the spatial modes induces spatial oscillations leading to richer dynamics, including frequency beating of in-phase and anti-phase modes.

In the excitable regime we show that the interaction of DS can be used to perform all-optical logical operations [5]. In particular it is possible to implement the AND, OR and NOT logic gates, providing complete logic functionality. Bits are represented by an excitable excursion rather than by a stationary solution. This provides a natural reset mechanism for the gates.

In many real systems, however, solitons are static, so oscillatory or excitable DS not generic. Here we also present a novel mechanism that generically induces dynamical regimes, such as oscillations and excitable behavior, in which the structure of the DS is preserved [6]. The mechanism which relies on the interplay between spatial inhomogeneities and drift, can be implemented under very general conditions, and allows for dissipative solitons in systems which do not have oscillatory states, such as the prototypical Swift-Hohenberg equation, to display oscillations and type I and II excitability.

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Nonlinear dynamics in semiconductor ring lasers

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Semiconductor Ring Lasers (SRLs) are a class of semiconductor lasers whose active cavity is characterized by a circular geometry. SRLs have attracted attention recently (see e.g. www.iolos.org) for mainly two reasons. On the one hand, SRLs are promising components in photonic integrated circuits due to their potential in applications such as all-optical memories and data processing. On the other hand, SRLs are prototypes for the large class of Z2 symmetric systems encountered in a wide number of physical systems.
Our contribution reviews the stochastic and nonlinear dynamical behavior of single-longitudinal and single transverse mode SRLs, putting emphasis on the experimentally observable dynamic features that are a consequence of the ring symmetry. Theoretically, these effects can be addressed in a generic way by investigating the invariant manifolds of the system.
We show how the ring symmetry can be broken in an experimentally controllable and reversible way, and what consequences this symmetry breaking may have on the dynamical behaviour of the device. In particular, we discuss mode hopping between multiple stable attractors present in the system [1, 2]. Also some unexpected behaviour of SRLs subject to optical injection is revealed [3]. We demonstrate excitability in a single SRL [4, 5] and pulse excitations in coupled SRLs [6, 7]. This suggests that SRLs are possible candidates for scalable optical excitable units, integrable on chip. Finally, we study SRLs subjected to feedback exhibiting e.g. square-wave oscillations [8].

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Nonlinear dynamics in VCSELs with crossed polarization reinjection

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Semiconductor laser output signal can be controlled by modulating its pumping current but this requires high speed electronics and it is usually limited in bandwidth due to the electrical characteristics of the laser diode and its mounting. For this reason the possibility of inducing emission of regular or chaotic signals in semiconductor lasers under steady conditions of bias current has attracted a lot of interest in the last two decades. These dynamics have been achieved by reinjecting a fraction of the emitted field back into the laser with or without some modification (polarisation rotation or frequency filtering for example). The dynamics hence obtained have the advantage of being self-sustained and robust in the parameter space. Moreover, the bandwidth limitations of the signal generated come from the internal time-scales of the laser (intraband and/or interband relaxation processes, photon lifetime) rather than from the electrical parasitic in the laser package. In this contribution we will review the non linear dynamics we have obtained taking advantage of the polarisation degrees of freedom of Vertical Cavity Surface Emitting Lasers (VCSELs). The scheme we have studied is based on crossed-polarization reinjection (XPR) where the laser output is split into its two linearly polarized components, LP-x and LP-y, and only one of these components (LP-x, say) is fed back into the laser after being rotated into the orthogonal polarization direction (LP-y) and with a delay τ_r. We will show that very regular square-wave emission can be obtained in each of the LP components with a period close to $2\tau_r$. This result occurs in VCSELs where the dichroism is strong enough and the emission occurs on a single polarization mode. In VCSEL with small dichroism —hence which may display bistability in some parameter range— it is possible to obtain square-wave emission by submitting the VCSEL to both XPR and weak polarization-selective optical feedback (PSF). Finally we will show that crossed-polarization reinjection together with PSF may lead to a pulsing behaviour in each polarisation component which exhibits the characteristics of a mode-locking regime.

MS4: Cardiac electromechanical modeling

Nonlinear field theories of continuum mechanics applied to cardiac dynamics and functions will be presented and discussed in this minisymposium. Different electromechanical formulations will address tissue dependent dynamics through a multiscale view of the problem. Clinical applications related to cardiac arrhythmias study and control will be treated by means of theoretical modeling of excitable biological media. A multiphysical approach towards a comprehensive analysis of heart tissue functions will be adopted.

Organizers: *S. Filippi and A. Gizzi*

Theoretical electromechanics of cardiac tissue

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A general theoretical framework for the formulation of constitutive equations of anisotropic electromechanical active media is presented. The approach is based on the additive decomposition of the Helmholtz free energy in elastic and inelastic parts and on the multiplicative decomposition of the deformation gradient in passive and active parts. We describe a thermodynamically sound scenario that accounts for geometric and material nonlinearities. The general approach is specialized then to a particular material model with the aim to address the behavior of heart tissue as biological media with hyperelastic contractile properties. The system undergoes rather large deformations, therefore the underlying biophysical dynamics cannot be described by means of the infinitesimal theory of elasticity. The electromechanical coupling is here introduced via the spatial gradient of the membrane action potential signal. We describe the solution of an evolutive uniaxial problem related to simplified electrophysiological models, discussing the numerical solution with respect to the emerging spatio-temporal nonlinear dynamics.

Suitable numerical methods and related modeling issues in the study of cardiac electromechanics

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We discuss the development of robust finite element methods and accurate mathematical models for the simulation of the cardiac excitation-contraction mechanisms at the cell and muscle levels. These are primarily based on the nonlinear elasticity theory and phenomenological and physiological descriptions of the mechano-electrical feedback. The link between contraction and the biochemical reactions at microscales is described by an active strain decomposition model. We address in detail the implications of different modeling and algorithmic choices into the electromechanical behavior of cells and muscle, and report on several preliminary results with a prototype model aimed to study the main aspects of the overall cardiac function. This corresponds to a joint work with D. Ambrosi (Mox-Milano), A. Quarteroni (EPF Lausanne), and S. Rossi (EPF Lausanne).

Modeling anisotropic myocardial contractions

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We present a mathematical model of myocardial contractions in the framework of finite elasticity with large distortions, coupled with reaction-diffusion equations representing the electro-physiological activity. Both models are implemented using anisotropic constitutive relations: we use stress-strain relations for fibre-reinforced materials, and anisotropic diffusion tensors for both membrane potential and calcium ions. The effects of these choices on the electromechanical behavior are presented and discussed.
Our distinguished point of view in modeling muscle contractions, firstly presented in [1] and successfully implemented by different researchers [2, 3, 4, 5, 6], is based on the notion of active deformation as opposed to that of active stress. The appropriate framework to set this idea is the theory of finite elasticity with distortions; these latter are the basic kinematics ingredient that describes the effect of muscle contraction, which is calcium–driven and occurs along directions which can be recognized as the lines of activations of the tissue.
We couple the mechanical model with a minimal electrophysiological model, presented in [7] and discussed in [8], based on just three state variables which, in general, allow sufficient flexibility to fit the most relevant cellular properties, such as the action potential duration (APD), the threshold of excitability, etc.
Our framework considers different velocities for the wavefront propagation and distinguishes two different conduction velocities: one for the fiber, the other for the plane orthogonal to the fiber. Such a feature is in accordance with the experimental findings reported in [9] where it has been shown that left ventricular myocardium has unique bulk conductivities associated with three micro-structurally defined axes.
We present some selected numerical experiments, mainly devoted to analyze and discuss this behaviour and to compare the performances corresponding to different electrical anisotropies.

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Atrial flutter: a model for studying mechano-electrical coupling in the human heart

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The heart is an electrically-controlled mechanical pump, where electrical impulses trigger mechanical contraction. In addition to the direct electro-mechanical branch, the heart function is regulated by a less-known feedback mechanism, called mechano-electrical coupling (MEC), which describes the influence of the heart's mechanical state on cardiac electrical activity. Despite the acknowledged role of MEC in both physiological and pathophysiological conditions, evidence for MEC in humans under real-life clinical scenarios is sparse.
We will present the results of clinical and theoretical studies led by our group on atrial flutter (AFL) rate variability, which provide evidence for the spontaneous manifestation of mechano-electrical interactions in the human heart. These data will be complemented with our recent investigation on the complex atrioventricular (AV) dynamics generated by the nonlinear nodal filtering of AFL activity, discussing results with potential clinical impact for the understanding of ventricular response generation in atrial fibrillation. AFL is a common supraventricular arrhythmia based on a high-frequency reentrant mechanism in the atria. AFL reentrant activity occurs in a mechanically-modulated environment, since extrinsic factors, such as ventricular contraction and respiration, induce changes in atrial volume which affect the geometrical and conductive properties of the reentrant circuit. The mechanical modulation perturbs the reentrant wave period, resulting in a variety of oscillatory patterns in the arrhythmia cycle length. To disclose the mechanisms generating AFL cycle length variability, we combined linear/nonlinear techniques for oscillatory system characterization with computer modeling. The construction of phase diagrams and the application of spectral analysis to atrial cycle length series demonstrated AFL spontaneous variability to be composed of two main oscillations occurring at the frequency of ventricular contraction and respiration [1]. Based on these results, a phenomenological model for AFL variability was developed assuming a phasic modulation of the reentry period by ventricular and respiratory forcing [2]. The model was able to reproduce 96% of atrial beat-to-beat variability, and predicted conditions of entrainment at specific ventricular frequencies, which were verified in patients under ventricular pacing.
In a subsequent study [3] we analyzed the complex dynamics of AV synchronization and the frequency-dependent block processes, which emerged when the high-frequency AFL inputs were transmitted to the ventricle. The application of firing sequence analysis to atrial and ventricular time series from AFL patients disclosed the presence of a wide spectrum of AV phase-locking patterns, whose transitions at changing atrial rate were regulated by a Farey sequence ordering. As well the existence of higher-order alternating rhythms was revealed at specific atrial rates. Computer simulations by a difference-equation model of AV conduction suggested the origin of these patterns in the combination of high-rate atrial inputs with the nonlinear recovery of excitability, dual pathway physiology and concealed conduction of the AV node.

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MS5: Nonlinear dynamics of genetic circuits

The study of genetic dynamics has been very popular during the last 15 years especially after great successes in designing the synthetic genetic circuits that demonstrate nontrivial behaviors such as switches, oscillations, and synchronization. These studies frequently generate the need for unusual multidimensional mathematical models and put new questions in front of nonlinear physics. The resulting cell can then be used for in vivo biosensing, synthesizing complex biomaterials, executing programmed cell death, or interfacing with microelectronic circuits by transducing biochemical events to and from the electronics. During MS we are going to consider the role of Quorum Sensing in the creation of collective dynamics of different genetic networks in E. Coli, as well as a novel synthetic network constructed in the yeast Saccharomyces Cerevisiae. A special attention will be paid to the mechanisms of multistability stimulated by inclusion of QS into the genetic network design. Microbiological systems are intrinsically noisy and both natural genetic networks and synthetic genetic networks must cope with the genetic noise evoked form the low copy number of the reactants. We will present parametric analysis of Repressilator equipped by QS to estimate to what extent noise simulated by standard method can result in the loss of robustness of genetic circuit dynamics.

Organizers: *E. Volkov and E. Ullner*

Emergence of oscillations in communicating bacteria

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We investigate the behaviour of a single cell, when alone and when part of a community, using a model describing the metabolic states of a population of quorum-coupled cells. The modelling is motivated by published experimental work of a synthetic genetic regulatory network (GRN) used in Escherichia coli cells that exhibit rhythmic behaviour across the population. To decipher the mechanisms underlying oscillations in the system, we perform numerical simulation and bifurcation analysis. In particular, we study the effect of an increase in population size as well as the spatio-temporal behaviour of the model. Our results demonstrate that in the model rhythmic behaviours are possible only in the presence of a high concentration of the coupling chemical that in turn depends on the cell density. This strongly suggests that population effects in GRN design need to be taken into consideration and form an integral part of the design process.

The role of noise in dynamics of repressilator with quorum sensing

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Coupled oscillators are relevant in all areas of life. The coupling between oscillators may significantly alter the dynamics ranging from the cease (quenching) of the oscillation to the multistability, where the system obtains several stable dynamical behaviors. Here, we use 3-gene Repressilator with coupling realized by the diffusion of a small molecule (autoinducer) that activates the expression of the one of the oscillator genes. The single oscillator of this type was recently shown to have two stable dynamical behaviors coexisting in the parameter space: oscillation and steady state. The coupling, acting as an additional positive feedback in the single oscillator, causes the emergence of the steady state further to the limit cycle of Repressilator. We study the effect of molecular noise, due to the small number of key molecules in the gene expression process, on the multistability of this system. We show that in the system with coupling the robustness of the oscillations, measured as the coefficient of variation (CV) of the period distribution, always increases with increasing transcription rate. Oppositely, the system without coupling demonstrates CV decrease with increasing transcription rate. We study the model with Hill-type cooperative repression of the proteins of Repressilator. In this model, transcription from the target promoters is described in terms of Hill function and is inversely proportional to the corresponding repressor protein concentration. We demonstrate that the noise level of the system is large due to the Hill-type cooperativity of the protein repression by comparing its dynamical properties with the model with explicit dimerization reactions, where protein dimers act as the repressor agents by binding to the promoter operator sites and preventing the transcription initiation. Therefore, the system with the Hill-type cooperativity is not anchored in either of the attractors, which leads to the less robust oscillation.

Dynamics of the quorum sensing switch: stochastic and non-stationary effects

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A wide range of bacteria species are known to communicate through the so called quorum sensing (QS) mechanism by means of which they produce a small molecule that can freely diffuse in the environment and in the cells. Upon reaching a threshold concentration, the signalling molecule activates the QS-controlled genes that promote phenotypic changes. This mechanism, for its simplicity, has become the model system for studying the emergence of a global response in prokaryotic cells. Yet, how cells precisely measure the signal concentration and act coordinately, despite the presence of fluctuations that unavoidably affects cell regulation and signalling, remains unclear. We propose a model for the QS signalling mechanism in Vibrio fischeri based on the synthetic strains lux01 and lux02. Our approach takes into account the key regulatory interactions between LuxR and LuxI, the autoinducer transport, the cellular growth and the division dynamics. By using both deterministic and stochastic models, we analyze the response and dynamics at the single-cell level and compare them to the global response at the population level. Our results show how fluctuations interfere with the synchronization of the cell activation and lead to a bimodal phenotypic distribution. In this context, we introduce the concept of precision in order to characterize the reliability of the QS communication process in the colony. We show that increasing the noise in the expression of LuxR helps cells to get activated at lower autoinducer concentrations but, at the same time, slows down the global response. The precision of the QS switch under non-stationary conditions decreases with noise, while at steady-state it is independent of the noise value. Our in silico experiments show that the response of the LuxR/LuxI system depends on the interplay between non-stationary and stochastic effects and that the burst size of the transcription/translation noise at the level of LuxR controls the phenotypic variability of the population. These results, together with recent experimental evidences on LuxR regulation in wild-type species, suggest that bacteria have evolved mechanisms to regulate the intensity of those fluctuations.

Re-engineering a genetic circuit into a synthetic tunable oscillator.

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Systems and Synthetic Biology use computational models of biological pathways in order to study in silico the behaviour of biological pathways. Here we use the tools of non-linear analysis to understand how to change the dynamics of the genes composing a novel synthetic network recently constructed in the yeast Saccharomyces Cerevisiae for In-vivo Reverse-engineering and Modelling Assessment (IRMA). Guided by previous theoretical results that link the dynamics of a biological network to its topological properties, through the use of simulation and continuation techniques, we found that the network can be easily turned into a robust and tunable synthetic oscillator, or a bistable switch. In particular, we found that changing the values of at least 4 parameters from the estimated values gives rise to sustained oscillations, with physically feasible period and amplitude. We found that at least two mechanisms cause the occurrence of Hopf bifurcation: multistep processing of gene products in the negative feedback loop and strong cooperativity in gene regulation. Using the continuation software DDE-BIFTOOL, we analyzed the robustness of the oscillations to parameters changes and varying initial conditions. Our results provide guidelines to properly re-engineering in vivo natural and synthetic networks in order to tune their dynamics.

PT2: Plenary talk

Importance of nonlinear features in continuous theories of active matter

Hugues Chaté

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After a general introduction to the statistical physics approach to active matter/collective motion, I will outline how controlled continuous theories can be derived from simple systems of self-propelled particles akin to the celebrated Vicsek model. Investigating the properties of the obtained nonlinear PDEs, I will stress the role and importance of their inhomogeneous solutions in describing many of the collective phenomena observed in the original particle-based systems.

CT1: Networks I

Heads or tails? Fitting growing networks' degree distributions to empirical data

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The maximum likelihood technique, as described in [1], is a reliable methodology to fit the parameters of a power law distribution to empirical data, which has proven to be very useful in many situations. However, when applied to growing network models, it should be used with precaution. In this contribution we show that for some common growing network models [2, 3, 4, 5] two things should be kept in our mind. First, the part of the degree distribution that matches more correctly the dynamics of the network is the head of the distribution (i.e., the region with low degree), and not the tail (the one with large degree); this is because the effects of the initial nodes are apparent in the tail of the distribution [6]. And second, the usual likelihood function used to estimate the parameters of the model should not be applied since it assumes identical and independent distributed variables and, as we prove, the degree of the nodes are correlated. Based on our analytical approximation of the expected degree distribution in these models, as well as on the approximation of the errors from this expected distribution, we propose a new methodology to fit these kind of models to empirical data, and compare our results to the usual fitting procedure with some empirical networks.

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Testing time series irreversibility using complex network methods

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The absence of time-reversal symmetry is a fundamental property of many nonlinear time series. Here, we propose a new set of statistical tests for time series irreversibility based on standard and horizontal visibility graphs. Specifically, we statistically compare the distributions of time-directed variants of the common complex network measures degree and local clustering coefficient. Our approach does not involve surrogate data and is applicable to relatively short time series. We demonstrate its performance for paradigmatic model systems with known time-reversal properties as well as for picking up signatures of nonlinearity in neuro-physiological data.

Effective trapping of random walks in heterogeneous networks

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Random walks (RWs) approach is the simplest but the most fundamental method which encapsulates essential properties of diffusive dynamic process. Here, we study the two basic quantities, the return to origin probability and the first passage time distribution of random walks on scale-free networks. The behaviors of those quantities as a function of time typically depend on the spectral dimension d_s in disordered fractal systems. However, we show that in scale-free networks, due to the heterogeneity of the number of connections of each node in scale-free networks, those quantities display a crossover decay behavior from $\sim t^{-d_s^{(\mathrm{hub})}/2}$ in early time regime to $\sim t^{-d_s/2}$ in later time regime, where $d_s^{(\mathrm{hub})} \to 0$ as the degree exponent λ approaches 2. This result implies that a random walker can be trapped effectively at the hub when $\lambda \to 2$. We discuss the origin of the effective spectral dimension by means of hand-waiving argument and applying the renormalization group transformation to deterministic hierarchical networks.

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Oscillatory networks with time-delayed pulsatile coupling

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Study of dynamics of oscillatory networks with time-delayed coupling is often a challenge. From the mathematical point of view such systems have infinite phase space dimension, which makes them difficult for theoretical analysis as well as for numerical simulation. On the other hand, delayed coupling is observed in many systems of various nature and is known to change their dynamics crucially, which conditions a great interest to the topic.
Here we present a novel approach to study of oscillatory networks with time-delayed coupling. The approach is based on the model of pulse-coupled oscillators described by the following dynamical system:

$$\frac{d\varphi_j(t)}{dt} = \omega_j + \sum_{k=1}^{N} f_{jk}(\varphi_j(t)) \sum_{t_k^p} \delta(t - t_k^p - \tau_{jk}), \qquad (1)$$

$j = 1...N$. Here φ_j is the phase of the j-th oscillator and ω_j stands for its natural frequency. t_k^p are the instants when the phase φ_k reaches unity, then it resets to zero and the k-th oscillator produces a pulse. The pulse spreads over the network and reaches each j-th oscillator after delay τ_{jk}. When a pulse reaches the j-th oscillator it causes its phase shift $\Delta\varphi_j = f_{jk}(\varphi_j)$. The function $f_{jk}(\varphi)$ is the so-called phase reset curve which describes interaction between the j-th and the k-th oscillators.
The above model was shown to be reducible to a finite-dimensional point map if the coupling is not very strong ($2FN < 1$ where F is the maximal value of all functions $f_{jk}(\varphi)$) [1]. This allows to study maps instead of studying full system (1) of difference-differential equations which is much simpler both theoretically and numerically.
Using the model of pulsatile delayed coupling we have studied oscillatory networks of various topologies and configurations. For a small circuit of two oscillators with small frequency mismatch 1:1 synchronization was studied and the so-called synchronization zones in the parameter space were found. It was shown that these zones can be observed for arbitrary large values of delays [2]. For larger mismatches $m : n$ synchronization was observed and the structure of Arnold tongues was studied.
In a small network with heterogeneous delays the multiple regimes of group synchronization were found. The phase relations between the oscillators were shown to depend on the value of the delay which allows to switch the phase clusters by means of the delay changing [3].
We also considered a large network of oscillators with homogeneous all-to-all delayed coupling. An analytical criterion of global synchronization stability was obtained. The most interesting result is that the criterion deals only with the slope of the phase reset curve and doesn't depend on its actual value. This allows synchronization by both positive (excitatory) and negative (inhibitory) coupling which fact was confirmed by numerical simulations [4].

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Dynamical robustness of complex oscillator networks

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Network robustness is one of the central issues in complex network theory. The studies on structural robustness of complex networks have focused on how tolerant the network connectivity is against removal of a fraction of the nodes. Percolation theory has been used to analytically derive the critical fraction of removed nodes, which induces a breakdown of the network structure. Based on the critical fraction, it has been shown that heterogeneous networks like scale-free ones are highly fragile to removal of hub nodes, i.e. nodes with many links [1].

In many real-world networks, the function of the network is maintained by structural connectivity as well as dynamical activity of the network components. For instance, biological systems would not keep normal functions without electrical and chemical activities of cells, proteins, and small molecules. Moreover, degradation of node dynamics could be a perturbation leading to a loss of the function in the entire network. Motivated by such networks, we developed a method to investigate robustness of dynamic behavior on complex networks of coupled oscillators [2] by modifying the framework for all-to-all networks [3]. We have shown that heterogeneous networks can be highly vulnerable to deterioration of oscillation dynamics in low-degree nodes, i.e. nodes with a few links.

In this presentation, we show our recent results on the dynamical robustness of complex oscillator networks. First, we demonstrate that the property of dynamical robustness largely depends on the coupling scheme between the connected oscillators. Second, we consider the heterogeneity of the potential dynamical activities of the individual oscillators. It is shown that networks composed of more heterogeneous oscillators are more dynamically robust.

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CT2: Pattern formation and dynamics

Emergence of spatiotemporal dislocation chains in drifting patterns

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Pattern formation far from equilibrium occurs in several domains of sciences through the spontaneous symmetry breaking of a ground state. Generally, the transition from an homogeneous state to a patterned one can be observed by modifying a single bifurcation parameter. Structures, generated at this first threshold of spatial instability, are generally stationary and can be either of (i) localized or of (ii) extended-periodic type. In extended systems, if we continued increasing the bifurcation parameter above threshold, the pattern can exhibit secondary instabilities commonly related to a stationary-to-propagating transition. These transitions in pattern forming systems can be classified into two types: i) spontaneous symmetry-breaking transitions, where the pattern will choose the direction of propagation depending on initial conditions and ii) induced parity-breaking transitions, when motionless patterns are exposed to drift forces. In the latter case, patterns are deformed and advected, which is usually related to convective instabilities. Under such regime, one expects a rich and complex spatiotemporal dynamics. Experimental observations of dislocations chains in drifting patterns have been reported in particle-laden flows inside a partially fluid filled, horizontal, rotating cylinder and a one-dimensional transverse Kerr-type slice subjected to optical feedback. Theoretical works have proposed that this dynamical behavior obeys to nonuniformities of control parameters, which induce local Eckhaus instability. However, the complete scenario that can trigger this spatiotemporal complex dynamics of drifting patterns have not been described yet. In the present work we study the spatiotemporal dynamics of drifting patterns. Based on a prototype model, *the inhomogeneous convective Swift-Hohenberg equation*, and its respective amplitude equation, we identify the mechanism of emergence of dislocations chains as a phase instability–Eckhaus instability–induced by an *inhomogeneous drift force*. This phenomenon is experimentally confirmed in a tilted quasi-one dimensional fluidized shallow granular bed mechanically driven by a harmonic vertical vibration.

Oscillatory Turing patterns in network-organized reaction-diffusion systems

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Both stationary and oscillatory instabilities were introduced by A. Turing [1]. While stationary Turing patterns are broadly known [2, 3, 4, 5, 6], the oscillatory instability, leading to traveling waves in continuous media and also called the wave bifurcation, is rare for chemical systems [7]. Here, we extend the theory by Turing to networks and apply it for ecological metapopulations with dispersal connections between habitats. Remarkably, waves do not appear in networks, but localized oscillations spontaneously develop in a subset of nodes, even though they are absent for isolated habitats. Oscillatory Turing instabilities are identified by us for all possible food webs with three predator or prey species, under various assumptions about the mobilities of individual species and nonlinear interactions between them. Furthermore, we found that the instability should be more common in ecological systems, as compared with chemical systems. Therefore, we suggest that they are generic in ecosystems and must play a fundamental role in metapopulation dynamics, providing a common mechanism for dispersal-induced destabilization of ecosystems. Although here our analysis has been performed on ecological systems, the constructed theory is general and it is also applicable to network-organized systems of other origins, such as coupled chemical reactors or biological cells.

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On the mechanisms for formation of segmented waves in active media

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We suggest three possible mechanisms for formation of segmented waves and spirals. These structures were observed in the Belousov-Zhabotinsky reaction dispersed in a water-in-oil aerosol OT/Span-20 microemulsion [1, 2].
The first mechanism is caused by interaction of two coupled subsystems, one of which is excitable, and the other one has Turing instability. It is shown that, segmented spirals evolve from ordinary smooth spirals as a result of the transverse Turing instability. We demonstrate that depending on the properties of subsystems different segmented spirals emerge.
For the second mechanism we suggest "splitting" of the traveling wave in the vicinity of the bifurcation point of codimension-2, where the boundaries of the Turing and wave instabilities intersect.
Finally we show that the segmented waves can emerge in some simple two-component reaction-diffusion models having more than one steady state, particularly in a FitzHugh-Nagumo model.

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Patterns in active media caused by diffusion instability

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Diffusion instability is a reason for different spatial-temporal patterns observed in physical, chemical and biological systems. Due to diffusion in a reacting system the uniform state may become unstable for the waves with eigenvectors from a certain range. There are two possibilities: either for these wave vectors one of the real eigenvalues of the linearized problem becomes positive, or a pair of complex conjugate eigenvalues acquires a positive real part. The first case is well known as the Turing instability and it usually results in formation of stationary non-uniform patterns. The second case – wave instability – gives rise to a great variety of spatial-temporal regimes. First we give a brief overview of patters observed experimentally in chemical systems. Then we discuss patterns which can arise in the vicinity of the wave bifurcation. We consider patterns which arise due to polymodal interaction in multidimensional space right after the wave bifurcation and obtain the conditions for them to occur. Namely we prove that depending on the strength of competition between the modes only two regimes are possible: if the competition is strong, only one of the amplitudes becomes nonzero and thus wave bifurcation results in a quasi one-dimensional travelling wave, while for low competition all the modes survive and a complex standing wave arises. Then we suggest a possible mechanism for a rather nontrivial phenomenon observed in experiment: the transition from standing waves to travelling waves with the half-wavelength. Our scenario is based on the hypothesis of resonance between the unstable mode, responsible for the standing wave, and the rigidly exited mode with a twofold wave number. Namely, the wave with a twofold wave number has also a duplicated frequency. We obtain conditions for the mode coupling strength parameters, under which this scenario is realized. The results of theoretical analysis are confirmed by numerical simulations.

Induced anisotropy in a pattern-forming reaction-diffusion system: Theory and experiments

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Self-organization is an important mechanism of pattern formation in living systems [1]. Usually, in Nature it does not occur as an isolated phenomenon but in presence of external perturbations that modify the diffusive dynamics of the organization processes [2]. We will present here results demonstrating the effect of a centrifugal force on Turing pattern formation induced by the Belousov-Zhabotinsty-areosol-OT reaction. This forcing is shown to modify the effective diffusion in the system in an anisotropic way [3]. We observe experimentally and numerically that the perturbation is able to modify the main characteristics of the pattern and even to force its transition to a different state [4]. For different values of the perturbation significant changes can be seen in both, the pattern wavelength and its morphology. The other relevant parameters of the system are analyzed and the results will be presented. A statistical mechanics approach was developed predicting the main features observed. We concluded, the morphology of the patterns presents a coupling with the symmetry of the perturbation.

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CT3: Social networks

Network analysis and urban bus flow in Madrid city

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Madrid city has a population of 3,254,950 on a extension of 60,683 hectares, it is divided into 21 districts. Districts are administrative regions into which subdivide the city to distribute and manage the exercise of civil or political rights, public functions, and services. Madrid city has also an urban bus network with 204 lines and 4,455 stops.
The goal of this research is to estimate several structural parameters of the urban bus network of Madrid and to analyze its traffic dynamics by means of Network Science [1, 2]. The urban bus networks of Madrid is abstracted in a graph $G = (E; L)$, where E is the set of nodes corresponding to the stops and L is the set of links between them, that connect the consecutive stops.
This study analizes a set of structural parameters (shortest distance between nodes, betweeness, clusters [3, 4, 5] and robustness [6, 7]). These features are studied both in the entire city and its districts.
The obtained results allow learning more about this network: to know its modularity, recognise its most important stops, to know the sensitivity to faults in the district networks (districts with highest and lowest sensitivity to failures), to find out the communication capacity for these networks (districts with the greatest and less number of inner and external communications), and to know the relation between the network and dweller density by district.
This study also investigate the urban bus flow between districts, the connection between this flow and the population of each district (i.e. its way of relation). This research can help to improve the transport networks: reducing the district sensitivity to failues, adding new stops or routes suitably, etc.

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The physics of information transmission in complex networks

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The amount of information exchanged per unit of time between two nodes in a dynamical network or between two data sets is a powerful concept for analysing complex systems. This quantity, known as the mutual information rate (MIR), is calculated from the mutual information, which is rigorously defined only for random systems. Moreover, the definition of mutual information is based on probabilities of significant events. The MIR is a fundamental quantity in science. Its maximal value gives the information capacity between any two sources of information (no need for stationarity, statistical stability, memoryless). Therefore, alternative approaches for its calculation or for the calculation of bounds of it are of vital relevance. In this talk, I will show a simple alternative way to calculate the MIR [1, 2] in dynamical (deterministic) networks or between two time series (not fully deterministic), and to calculate its upper and lower bounds without having to calculate probabilities, but rather in terms of well known and well defined quantities (e.g. Lyapunov exponents, expansion rates, and dimensions) in dynamical systems. As possible applications of these bounds, I will briefly present a series of applications where this theoretical approach can be used to better understand complex systems, such as the brain, simulated neural networks, coupled oscillators and maps, the DNA, and stochastic systems. I will give special emphasis to shed light into the relationship among information, synchronisation, the network topology, time recurrences, and the correlation decay, in these complex systems.

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What is a leader of opinion formation in bounded confidence models?

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Taking a decision in democratic social groups (societies) is based on the opinion of the majority or on the consensus, if it is the case. Personalities and opinions of individuals constituting a social group in different stages of its development are used to be heterogeneous. The difference in opinions is indeed a motive to changes in a social group. So, the study of opinion dynamics is of great interest in analyzing social phenomena. Among the different models of opinion dynamics, bounded confidence models have been studied in different contexts and shown interesting dynamics, particularly in clustering, polarization and fragmentation of opinions, and influence of extremists [1, 2, 3]. In [4] we proposed a new bounded confidence model and studied the self-formation of opinion in heterogeneous societies composed by agents of two psychological types, concord (C-) and partial antagonism (PA-) agents. In this work we study the influence of “leaders” on the clustering of opinions in small world (SW) networks, starting the opinion dynamics from the uniform initial distribution of opinions in the network. Mixed C/PA-societies along with the pure C- and PA-society are studied. The influence of the leader’s connectivity in the network, his toughness or tolerance and his opinion on the opinion dynamics is studied as a function of the initial opinion uncertainty (tolerance) of the population. Numerical results obtained with leaders at low, high and average tolerance show complex bifurcation patterns of the group opinion; a decrease or even the total lost of control of the leader over the society is observed in different intervals of tolerance of agents in the case of C/PA-societies. We found that in the C-society a leader showing high opinion tolerance has more control over the population. In the PA-society a leader changes the bifurcation pattern of group opinion in a drastic and unexpected way, contrary to the common sense, and generates stronger polarization in the opposite opinion groups; the connectivity of the leader is an important factor that usually improves the adhesion of agents to the leader’s opinion. A low tolerance (authoritarian) leader has greater control over a PA-society than that of a high tolerance (democratic) one; the opposite result is obtained in the C-society.

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Strategies for the diffusion of behaviors in social networks

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Social networks have been identified as valuable representations of the relations between individuals of a social system. To understand the behavioral spread in which individuals are influenced by their peers is crucial for allocating resources and achieving success of a community intervention focused on the spread of a behavior. We propose a simulation model for identifying an efficient set of nodes to initialize a diffusion process in a social network in order to accelerate the diffusion process. We defined different sets of initial spreaders using 1) centrality measures of the network: Hubs (highest degree), Intermediaries (highest betweenness) and Closest (highest closeness) and 2) using local structural properties derived from the communities detected in the network: Community Bridges (highest number of links with other communities) and Community Hubs (highest number of links with the own community members). We simulated the canonical susceptible-infected model in the Erdös-Rényi random graph, Watts-Strogatz small-world and Barabasi-Albert scale-free network topologies by varying the initial set of spreaders, the contact probability and size of the networks. The results of the simulation suggest that Community Hubs perform equal or better than Hubs as the size of the Erdös-Rényi network increases. Community Bridges perform better than the other four sets of nodes for the Small-World topology independently of the network size. Hubs perform better than the other four sets of nodes for small scale-free networks. As the scale-free network size increases, Community Bridges equalizes the Hubs performance. Our sensitivity analysis for the Scale-Free topology suggest that Community Bridges perform better for low clustered networks whereas sets defined by centrality measures (Hubs and Intermediaries) perform better for high clustered networks.

Maintaining stable distribution in evolving supply-demand networks

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The ability to design a transport network such that commodities are brought from suppliers to consumers in a steady (the rates at which loads are transported are constant), optimal (the transport costs are minimal), and stable (the network is unaffected by attacks or topology changes which may trigger flows to surpass an edge capacity) way is of major importance for nowadays distribution systems. In this work, we provide general analytical values (plus manageable margins) for the edge's capacities that a conservative supply-demand network should have in order to maintain a steady optimal stable distribution system for evolving topologies and/or changing locations of suppliers and consumers. In other words, we are able to provide rigorous and simple strategies to evolve (nodes or edges are added or removed) or modify (change the suppliers and consumers positions in the network) a supply-demand network preserving its stability.

CT4: Neural dynamics

Spontaneous segregation of excitation and inhibition in a system of coupled cortical columns

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The balance between excitation and inhibition is of crucial importance for proper brain performance. At a cellular level the excitability of a neural network is ruled by excitatory and inhibitory synapses, the first ones inducing the activation of their downstream connected neurons and the latter depressing or silencing this activation. This can be related with the oscillatory characteristic dynamics seen in *in vivo* recordings, such as LFP or EEG , and in *in vitro* recordings, such as brain slices. Anomalies in the action of excitation and inhibition can lead to brain disorders such as epilepsy, autism or schizophrenia. We aim to work at a mesoscopic scale, which comprises populations of thousands of neurons, so as to study the distribution of excitation and inhibition in a spread area in the brain. To do so, we use a system of coupled modified Jansen and Rit models, which are a mean field approximation of the activity of a wide population of cortical neurons, and characterize their excitatory or inhibitory intrinsic dynamics. Our model units, the aforementioned Jansen and Rit models, describe the activity of three coupled neuronal populations: excitatory/inhibitory interneurons and pyramidal cells. The output or observable in our model can be related with mesoscopic signals such as EEG, MEG or LFP, being so the income average postsynaptic potentials (PSPs) from neighboring interneurons to the main population of pyramidal cells. We also added a regular input into the model to mimic the action of any external oscillatory signal. This input gives rise to very complex dynamics, ranging from regular to chaos. We compute the complexity of the signals by using the *regularity* of the signal, related with their autocorrelation function. The lowest regularity the highest complexity and vice versa. The key in our model is the network topology and coupling characteristics: a scale-free network of excitatory and inhibitory coupled cortical units was studied for different increasing excitatory and inhibitory coupling strengths. This coupling strengths -α for the excitatory and β for the inhibitory links- are the control parameters for our system and, alongside with the network, are the responsibles for the complex distribution of the mesoscopic dynamics in our model. We have seen signs of clear separation of our cortical units into excitatory and inhibitory dominating dynamics, allowing for high synchronization and low regularity -thus preserving complexity- coexisting with some nodes in a regular regime. This separation seems to be inherent to the constructed network and comes out to be an emergent property of the system. With this work we can shed light into the relationship between topology and dynamics as well as giving a novel view of the distribution of excitation and inhibition in the brain at a mesoscopic scale.

Critical slowing down and decrease in resilience of neuronal networks precede transition to epileptic seizures in vitro.

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Transition to epileptic seizure represents a sudden and abrupt shift between distinct dynamic regimes of the brain. In some complex systems transition between contrasting states can be preceded by detectable changes in their dynamics. These changes manifest as early warning signals, which mark the approach of the critical threshold. The aim of this study was to examine whether seizures are preceded by detectable changes, which would enable forecasting of the approaching seizure. Experiments were performed in vitro in rat hippocampal slices perfused with artificial cerebrospinal fluid containing low-calcium (0.2 mM) or high-potassium (8 mM). Field potentials from the hippocampal CA1 region were recorded using multiple extracellular electrodes. To actively test the dynamical state of the CA1 network we used electrical stimulation of the alveus to evoke anti-dromic evoked potentials. In the low-calcium model, seizures were preceded by a progressive increase in lag-1 autocorrelation and variance of preictal data when compared with surrogates. These changes ran in parallel with spatial expansion of preictal activity and increased synchronization. On a cellular level these early warning signals were accompanied by a progressive increase in neuronal firing. These observations suggested that seizures were preceded by a gradual increase in neuronal network excitability. To determine the excitability level we examined the response of the network to antidromic stimulations. With an approaching seizure, the duration of the responses increased and recovery from them gradually slowed down. Immediately preceding the seizure even very weak stimulations could trigger a seizure. In the high-potassium model, preictal dynamics had similar features, when seizures were preceded by increase in lag-1 autocorrelation and signal variance. Our study demonstrates that early warning signals and response to external perturbations have the potential to detect preictal changes in the dynamics of epileptic neuronal networks. The behaviour of the epileptic neuronal networks displayed features similar to critical slowing down and was associated with a progressive decrease in the network resilience. The lowest resilience was observed immediately before the onset of a seizure, when weak internal or external perturbations could tip the network dynamics to seizure. Supported by Karel Janecek Endowment in Support of Science and Research (2012/10) grant and Czech Ministry of Health grants (IGA NT11460-4/2010, IGA NT 14489-3/2013).

Bistability in neuronal firing induced by the network correlation feedback

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Multistability of firing states in neuronal networks is considered as one of possible mechanisms of memory organization and information storage in the brain. Such multistability can emerge from bistable dynamics of local neurons and/or from the specific structure of interneuron connectivity. In this work we show that these two factors are not necessarily needed. The network multistability can be generated dynamically by means of a correlation feedback in a network spiking neurons with an unstructured connectivity. We consider a Hodgkin-Huxley neuron stimulated by a Poisson pulse train signal. These pulses may come from other cells of the network and activate a number of synaptic contacts in the neuron dendritic tree. We assume that in spontaneous dynamics these events are independent. Neuron response represents a sequence of postsynaptic potentials leading to a response spike if the excitation threshold is exceeded. Calculating the dependence of the output firing rate on the input frequency we found that it is given by a monotonic curve tending to some saturation level what fits well experimental observations. Next we assume that the spike propagates along divergent/convergent architecture of the network synaptic pathways activating the other network neurons. Because of complex connectivity of real networks it is hardly possible to identify particular paths followed by the particular spike. However, we can monitor how changing in the output spiking rate influences the overall network activity and, hence, the average frequency of the neuron input. If such influence exists we can characterize it as a certain level of correlation between the input and the output signals of the network neuron. Thus, the input firing rate becomes a dynamical variable that depends on the neuron firing state. We found that for increasing strength of such correlation feedback the neuron dynamics became bistable. The network neuron with originally monostable dynamics acquires two distinct locally stable firing states. It immediately means that the overall network dynamics becomes multistable. The transitions between the states may be caused by external sensory signals. Thus, the presence of correlation feedback mediated by network signal propagation may generate a dynamical memory capable to encode and store information as neuron states with different firing rates.

The mechanism of stochastic amplification explain fluctuations in the cortex

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Local field potentials of cortical neurons can switch between quiescent (down) and active (up) states (i.e. are bistable) generating slow oscillations which are known up-down states. Despite a large number of studies on Up-Down states, deciphering their nature, mechanisms, and function remain challenging tasks. Recent experimental evidence, shows that a novel class of spontaneous oscillations emerge within the Up states but not in down states. Remarkably, this rhythm within Up states seems to be an emergent or collective phenomenon given that individual neurons do not lock to it and they mostly remain unsynchronized. Here we shed light on these findings by using different simple models for neural activity involving different complexity levels. Our conclusion, supported by both theory and computer simulations, is that the collective non-linear phenomenon of “stochastic amplification of fluctuations” – previously described in other contexts such as Ecology and Epidemiology – explains in an elegant and parsimonious manner, beyond model-dependent details, this neural rhythm emerging in the Up states but not in the Downs. We also discuss the possibility of observing (Shilnikov) chaos in these simple models of overall brain activity.

Anatomo-functional organization in brain networks

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There are several studies focused on comparing rsFC networks with their structural substrate [1, 2]. However an accurate description of how anatomo-functional connections are organized, both at physical and topological levels, is still to be defined. Here we present an approach to quantify the anatomo-functional organization and discuss its consistency.
Ten subjects were scanned twice on a 3T General Electric MR scanner. The acquisition protocol consisted of a high resolution T1, six minutes resting state fMRI scan and 26 encoding diffusion directions DWI. T1 images were parcelled in 88 gray matter ROIs. DTI were built from DWI, and were set as inputs to the tracking algorithm defined in [3] obtaining one structural connectivity network (SCN) per subject and time point. fMRI were pre-processed, and then co-registered to the b0 image. Voxel time courses belonging to each ROI were band-pass filtered [0.01–0.09 Hz] and linearly detrended, and finally they were averaged. Functional connectivity networks (FCN) were obtained performing Pearson linear correlations between all ROI time courses. We computed the topological and physical Rentian scaling (RS) of the networks [4]. With the physical RS, we study the relationship of the number of nodes and the number of links that are within/crossing an imaginary cube of random centre and size. With the topological RS, we define the same relationship but in communities of nodes where the within community connectivity has been maximized compared to the inter communities connectivity. This relationship for both physical and topological RS is represented in log-log space and by least square fitting it is possible to obtain the slope of this curve (in linear region), which are called the physical p and topological p_t Rent exponents. The expected minimum Rent exponent is defined as $p_{min} = max(0.66, p_t)$. The closer p is to p_{min} the more optimized the network is [5].
We found non-significant differences across network modalities and acquisitions for p_{min} $(\alpha = 0.99)$. However, they were significantly higher for both modalities in the second acquisition, and SCN showed lower values than FCN in both acquisitions $(\alpha = 0.99)$. The distance between p and p_{min} was computed as an indicator of organization of SCN and FCN. This was significantly lower in SCN than in FCN $(\alpha = 0.99)$, revealing that the organization in FC is more random and less structured than in SC. We also obtained the Rent exponents for randomized versions of the original networks. p_{rdm} and $p_{t_{rdm}}$ were higher than their respective p and p_t $(\alpha = 0.99)$ for both acquisitions and modalities, indicating that the networks were more organized than what would be expected if they were only driven by random forces.

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CT5: Transport phenomena

Polygonal billiards: Spectrum and transport

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In this contribution we will consider dynamical and transport properties of polygonal billiard tables, a class of dynamical systems where, notwithstanding remarkable results, many - quite basic- open problems still remain [1].
In particular we investigate a square annular billiard, where former work indicated non trivial scaling properties of the spectrum as well as anomalous transport once the systems is lifted to a non-compact space [2]. The emphasis will be on relationships that connect spectral and dynamical features, involving multifractal indices of the spectral measure, and on numerical and theoretical indications [3] that suggest how the lifted system may provide an example of "weak anomalous transport" [4], *i.e.* where the moments' spectrum of the diffusing variable X, has the asymptotic behavior

$$\langle |X_t - X_0|^q \rangle \sim t^{\alpha \cdot q},$$

for all $q > 0$, but with $\alpha \neq 1/2$, as is the case for normal, gaussian transport.

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Temperature resistant optimal ratchet transport

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Stable periodic structures containing optimal ratchet transport, recently found in the parameter space dissipation versus ratchet parameter [1], are shown to be resistant to reasonable temperatures, reforcing the belief that they play the fundamental role to explain the optimal ratchet transport in nature. Critical temperatures for their destruction are obtained numerically and are valid from the overdamping to close to the conservative limits. A region where thermal activation of the ratchet current takes place is also found, and its underlying mechanism unveiled. Results are demonstrated for a discrete ratchet model and generalized to the Langevin equation with an additional external oscillating force [2].

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Mathematical model of self-organizing and adaptable intracellular transport network

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We present direct simulation of cellular microtubular transport system self-organization and cargo transfer. Our main aim was to describe mechanisms that are necessary for forming intracellular transport network capable of adaptive changes of cellular metabolic state and tasks. The model is an extension of the model of microtubule self-organization in melanophores (pigment cells) [1].
Our model describes two coupled processes. First is polymerization and depolymerization of microtubules, second is fast cargo transfer along microtubule network. First block is stochastic and describes each microtubule individually with plus- and minus-end coordinates. Second block consists of system of diffusion-convection equation and boundary conditions that may describe endocytosis or isolated cell. Equations were numerically solved with finite-volume method.
Then we simulate the experiment on intracellular endosome transport, described in [2], and obtained the patterns similar to the original experiment, which are positive correlation between total number of endosomes and mean distance from nucleus to endosomes, negative correlation between mean endosome size and total number of endosomes, negative correlation between mean endosome size and mean distance from nucleus. We also consider the factors influenced on general shape of multisection transport network.

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Noise induced phase transitions and coupled Brownian motors: Non standard hysteretic cycles

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Recent work [1, 2, 3] have shown the possibility, through a noise induced symmetry breaking leading to a nonequilibrium phase transition, of obtaining a set of coupled Brownian motors. It was also shown [4] that in some parameter region such a system could show negative mobility (that is motion opposed to the applied force) and anomalous hysteretic behavior (clockwise in opposition to the usual counter-clockwise). Using an explicit mean-field approximation and colored multiplicative noises, it was found a contraction of the ordered phase (and re-entrance as a function of the coupling) on one hand, and a shift from anomalous to normal hysteretic behavior on the other [5]. This behavior was obtained in systems presenting a noise induced phase transition that originates from a short time instability. Here we discuss a similar system, but where the noise induced phase transition is originated in an entropic mechanism [6]. Some preliminary studies that exploits such a mechanism indicate the possibility of obtaining no standard hysteretic cycles: anti-clockwise but showing a staircase-like structure. Depending on the parameter region, the hysteresis diagram could have one or more blocks, that can be explored as a whole or step by step, opening the possibility of exploiting it as a noise-controlled multipurpose logic gate.

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From the physics of interacting polymers to optimizing routes on the London underground

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Optimizing paths on networks is crucial for many applications, from subway traffic to Internet communication. As global path optimization that takes account of all path-choices simultaneously is computationally hard, most existing routing algorithms optimize paths individually, thus providing sub-optimal solutions. We employ the physics of interacting polymers and disordered systems to analyze macroscopic properties of generic path-optimization problems and derive a simple, principled, generic and distributive routing algorithm capable of considering simultaneously all individual path choices. We demonstrate the efficacy of the new algorithm by applying it to: (i) random graphs resembling Internet overlay networks; (ii) travel on the London underground network based on Oyster-card data; and (iii) the global airport network. Analytically derived macroscopic properties give rise to insightful new routing phenomena, including phase transitions and scaling laws, which facilitate better understanding of the appropriate operational regimes and their limitations that are difficult to obtain otherwise.

CT6: Synchronization

Generalized synchronization of coupled nearly-identical dynamical systems

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In this paper we study generalized synchronization of coupled nearly-identical dynamical systems on a network. We extend the formalism of the master stability function for analysing the stability of the generalized synchronization of coupled nearly-identical dynamical systems. Using this master stability function we construct synchronized optimized network from a given network with arbitrary topology and fixed number of links and nodes. We study some topological properties, such as degree distribution, clustering coefficient, betweenness and closeness centrality and average shortest path length of the optimized networks. In the optimized networks the nodes with parameter value at one extreme are selected as hubs and also these nodes have higher betweenness and closeness centrality than the other nodes of the network. The pair of nodes with larger parameter difference are preferred to create links in the optimized networks. The optimized networks are likely to have higher clustering coefficients than the initial random networks.

Collective almost synchronisation in complex networks

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This work introduces the phenomenon of Collective Almost Synchronisation (CAS) [1], which describes a universal way of how patterns can appear in complex networks for small coupling strengths. The CAS phenomenon appears due to the existence of an approximately constant local mean eld and is characterised by having nodes with trajectories evolving around periodic stable orbits. Common notion based on statistical knowledge would lead one to interpret the appearance of a local constant mean field as a consequence of the fact that the behaviour of each node is not correlated to the behaviours of the others. Contrary to this common notion, we show that various well known weaker forms of synchronisation (almost, time-lag, phase synchronisation, and generalised synchronisation) appear as a result of the onset of an almost constant local mean eld. If the memory is formed in a brain by minimising the coupling strength among neurons and maximising the number of possible patterns, then the CAS phenomenon is a plausible explanation for it.

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Synchronization and self-organization in multifrequency oscillator communities

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Models in the form of coupled nonlinear oscillatory ensembles essentially appears in many physical systems such as Josephson junction circuits, electrochemical oscillators, pedestrian induced oscillations of footbridges. Similar models are also used in biology, for example in studying of neural ensembles dynamics and systems describing circadian clocks in mammals. In many cases analysis of large ensembles consisting of heterogeneous oscillators can be successfully handled in phase approach [1, 2]. Various applications and prevalence of such models give rise to systematic study of phase oscillator ensembles [3, 4]. Perhaps the most popular and investigated phase model is the Kuramoto model [1] which describe the dynamics of the phases of self-sustained oscillators with **close frequencies** and global sinusoidal coupling. In contrast to previous works we consider the case of **multifrequency** oscillator communities, where natural **frequencies** of interacting groups **differs significantly**. In this setup we cannot perform standard method of averaging since communities have strongly diverse periods of oscillations. In our work we extend the theory for two different cases of multifrequency populations in the phase approximation:
(i) in first part we focused on the **non-resonant interaction** [5]. In this case we assume that there are several groups of oscillators and that the frequencies within each group are close to each other but are strongly different between the groups. In this situation, the coupling within the group is resonant, like in usual Kuramoto-type models, but the coupling between the groups can be only non-resonant. We employed the Ott-Antonsen theory and demonstrated a variety of possible nontrivial regimes due to non-resonant interaction: coexistence and bistability of synchronous states as well as periodic oscillations. For a large number of interacting groups, more complex states appear: a stable heteroclinic cycle and a chaotic regime.
(ii) In the second part of the work we have considered the case of **resonant interaction** [6], where basic population frequencies strongly diverse from each other, but are in a combinational resonance. We focused in this work on a detailed description of the most elementary three-community "triplet" resonance $\omega_1 + \omega_2 \approx \omega_3$, and two-community high-order resonance $\omega_1 : \omega_2 = m : n$. This is accomplished by using the Ott-Antonsen ansatz allowing one to write a closed system for complex order parameters for certain cases. Remarkably, for triplet of populations the inter-community interaction not only shifts relative phases of the communities mean fields, but influences internal synchrony within communities. We have demonstrated how the inter-community interaction can induce or suppress internal synchronization. For two interacting populations with high-order resonances we found remarkable regimes of cluster synchronization.

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Chaotic synchronization on scale-free hypernetworks

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The concept of hypernetworks generalizes that of networks in such a way that groups of p nodes ($p \geq 2$) are connected by hyperedges. Chaotic synchronization on hypernetworks can be studied if chaotic oscillators are placed in the nodes and coupled along the hyperedges by coupling functions which are in general nonlinear and which are reduced to linear diffusive coupling for $p = 2$. Using the Master Stability Function approach it can be shown that the problem of stability of the identical synchronization state for the hypernetwork of oscillators is equivalent to that for a weighted network of diffusively coupled oscillators, where the weigts of coupling between each pair of nodes are equal to the number of different hyperedges simultaneously connecting this pair of nodes. In this contribution synchronization of Lorenz oscillators on complex scale-free hypernetworks is investigated; such hypernetworks are generalizations of complex scale-free networks and can be obtained using a similar preferential attachment algorithm for groups of m new nodes attached to $p - m$ existing nodes by hyperedges rather than for individual new nodes attached to several existing nodes by edges. For a proper choice of the coupling function identical synchronization can be obtained for p even, and the highest propensity for synchronization is exhibited by hypernetworks with $m = p/2$. Besides, such phenomena as antisynchronization, coexistence of the synchronized and amplitude death states with riddled basins of attraction and quasiperiodic states are observed in numerical simulations.

Resilience of synchronization against topological changes in resonant and non-resonant coupled oscillators

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Communication through a mediator is a robust mechanism to achieve a high degree of synchronization in large populations of oscillators even when the population is heterogeneous. Some examples of this behavior include yeast cells in a common medium [1], pedestrians walking in a bridge [2] or star-coupled semiconductor lasers [3]. In this context a progressive transition from the incoherent state for active oscillators or a sudden transitions from the quiescent state for passive oscillators have been reported when the number of oscillators is above a critical value. All those systems consider the elements coupled all-to-all in a extremely symmetric way, all see the same mean field. Real systems can have several kinds of interactions and while global coupling may be present, pairwise coupling between some elements may also be present. The question of how pairwise coupling changes the results obtained with global coupling remains open.
In particular we consider N Stuart-Landau oscillators, z_j, globally coupled through a common linear damped oscillator, F, and pairwise coupled by direct coupling:

$$\dot{z_j} = (\mu + i\theta_j)z_j - |z_j|^2 z_j + k_A^{(1)}(F - z_j) + k_B \sum_{k=1}^{N} B_{jk} z_k, \quad (1)$$

$$\dot{F} = (-\gamma + i\Delta)F + k_A^{(2)} \sum_{j=1}^{N} z_j. \quad (2)$$

where for oscillator j, μ controls the amplitude of oscillation and θ_j the detuning frequency. γ is the damping parameter of the hub, and Δ its natural frequency. B_{jk} can be positive or negative and defines the topology of the pairwise couplings, and k_A and k_B are positive coupling strengths.
For resonant homogeneous oscillators ($\theta_j = \theta = \Delta$) we use the Master Stability Function formalism recently generalized for group synchronization [4] to study the effect of different couplings on the stability of synchronization. When $B_{jk} \geq 0$ for all pairwise couplings synchronization is stable. In turn, if some B_{jk} are negative identical synchronization is still observed for a broad range of coupling strengths, while outside this stable region it leads to a rich variety of coexisting dynamics such as inhomogeneous amplitude synchronization or rotating waves of different orders.
For a heterogeneous population we show that four different transitions to synchronization can be observed when the Stuart-Landau's and the hub are nonresonant, that is, synchronization is reached smoothly or suddenly from either the quiescent or the incoherent state. Surprisingly, heterogeneity in passive oscillators helps the system to synchronize when compared with the homogeneous case which is discussed in terms of the smaller detuning of part of the population with respect the hub. The effect of pairwise interactions is also discussed under these conditions.

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CT7: Methods in nonlinear dynamics

Fluctuations in driven polymer translocation

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The role of thermo-fluctuations in the course of driven translocation of a long polymer is investigated by means of a molecular dynamics simulations. Our approach is based on the assumption that the translocation coordinate $s(t)$ is is a stochastic variable governed by a velocity Langevin equation. With this in mind we derive the corresponding Fokker-Planck equation which has a nonlinear drift term and a time-dependent diffusion coefficient $D(t)$. Our direct MD simulation shows that the driven translocation follows a super-diffusion with $D(t) \propto t^{\gamma}$ with $\gamma < 1$. Using this finding in the numerical solution of the Fokker-Planck equation demonstrates that under relatively small driving forces fluctuations can facilitate the translocation process. Moreover , we find that the the scaling of the translocation time (τ) with polymer length N is affected by fluctuations: the exponent α in the scaling relation $\tau \propto N^{\alpha}$ is decreases due to fluctuations. In the non-driven case the translocation is slightly subdiffusive and can be treated within the framework of fractional Brownian motion

Causality detection for short-term data

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Causality detection based on time-series data has attracted great attention and provides insight for the regulation relationship in complex systems. The famous Granger causality [1] definition has widely been accepted as a criterion for the detection of causality in various disciplines. Recently, some new type of causality detection method has also been proposed to compensate the limit of Granger causality [2]. However, these methods are all based on the assumption that the underlying time-series is sufficiently long. Nevertheless, due to the cost of measurement or the limit of experimental technique, some time-series data shows short-term character, among which the microarray data for gene expressions comes as a representative example. For these short-term data, the originally method cannot take effect or the yielded result cannot be convincing. Therefore, an interesting question arises that whether we can detect causality between two short-term time-series data.
In this work, we will revisit the nonlinear state space reconstruction technique and propose a method to detect causality based on the smoothness of the map between two reconstructed attractors. With the proposed method, we will investigate the possibility to detect causality between two short-term time-series data. To be specific, provided two time-series x(t) and y(t), we will first reconstruct the attractor X and Y respectively, with the standard delayed embedding technique. Then we will propose a criterion to describe the smoothness between the two attractors X and Y, which will indicate the causal relation between the two time-series. Finally we will design some index to compute the causality form x to y and vice versa. Both theoretical analysis and numerical results for some standard test models will be included in our work.

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Theory of heteroclinic computation

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A broad range of systems exhibit complex heteroclinic networks of saddles and are thereby capable of universal types of computation in the presence of simple coding and decoding schemes. Heteroclinic cycles within such networks of states constitute promising candidates for representing solutions of computational tasks. Still it remains an open problem under which conditions systems with heteroclinic networks can actually perform all of a computation, with no computational load shifted to encoding or decoding. This constitutes a key question for potential future applicability of the heteroclinic computation paradigm, because restrictions in the core system itself would limit its use.

Here we develop the fundamentals for a theory of computability through processes that exploit switching across heteroclinic networks. An input-output function is *computable* if and only if for each input (out of a collection of all possible inputs) its desired outputs can be represented uniquely. Given such compatibility conditions, we suggest a method of finding system modifications to admit complex computations. In particular, we reduce the problem to a standard combinatorial optimization procedure by modifying the coupling strengths of the original system such that any given input-output function can be realized.

As a result of the broken network-symmetry there is a tradeoff between computability of functions and their initialization in state space, i.e. whether the system can perform all desired computations starting from one given initial state. This suggests a feasibility hierarchy of solutions that we name non-existent, initializable and transitive.

In summary, we present a novel concept of computability in (arbitrary) systems exhibiting heteroclinic networks. The concept is system-independent and may find its way into hardware applications, e.g. in electronic circuits, micro-mechanical oscillators, or coupled lasers.

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Granger causality in high-dimensional systems using restricted vector autoregressive models

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Granger causality stems from econometrics and regards the effect of one variable in the time evolution of another variable. Measures of Granger causality have been employed for the investigation of the inter-dependence structure of complex systems, where each observed variable may also represent a subsystem. Though most complex systems are inherently nonlinear and thus only nonlinear Granger causality measures are in principle appropriate, often the limitations of noise and time series length suggest the use of linear Granger causality measures. In the presence of many observed variables, even linear Granger causality measures may collapse due to the instability of the estimation of vector autoregressive models (VAR) of many variables on time series of limited length (large number of coefficients of lagged variables to be estimated).
Here, we investigate VAR models with constraints, also referred to as dynamic regression models (DR), derived under different selection methods for the lagged variables, i.e. the top-down strategy, the bottom-up strategy, the so-called Lasso method, and a recently developed technique called backward-in-time selection (BTS) [1].
For the Granger causality from a driving variable X_i to a response variable X_j, $X_i \rightarrow X_j$, we concentrate on the presence of X_i in the representation of the DR model for X_j estimated on the time series of K observed variables $X_1, \ldots, X_K$. If X_i is present, then there is Granger causality and it is quantified by the standard conditional Granger causality index (CGCI), otherwise CGCI is exactly zero. The main advantage of this approach is that the DR representation involves only a subset of the set of all KP lagged variables, where P is the maximum lag, and thus it can be applied even in problems where $KP > N$. In this context, the top-down strategy for the selection of DR is inferior to the other methods. We assess the DR representation from the four selection methods and the complete VAR representation in terms of the sensitivity and specificity of CGCI. For this a simulation study is conducted using linear and nonlinear, deterministic and stochastic, low and high-dimensional systems and different lengths of generated time series. For nonlinear systems, we compare the DR and VAR representation with the non-uniform mixed embedding obtained by a criterion of conditional mutual information [2].
Further, we apply the DR representation for the estimation of CGCI to multi-channel scalp electroencephalographic (EEG) recordings of epileptic patients, containing epileptiform discharges (ED), i.e. interictal discharges and subclinical epileptic seizures. We estimate the brain connectivity before, during and after ED. We investigate if CGCI with DR representation can detect alterations in the connectivity structure under different states.

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Inference of time-evolving structural and functional relationships from networks of interacting oscillators

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The time-variability of dynamics is a common characteristic in oscillatory systems that interact freely with each other and/or with the environment. In nature, such non-autonomous systems arise in diverse areas, including geophysics, biology and astrophysics. Often the systems are found to coexist and interact in a larger number, forming networks of interacting oscillators. These form a large and important group of physical systems, and can introduce a higher complexity, both in structure and functional behavior. For example in neuronal networks, the existence of spatial and spatial-temporal correlations, collective or partially collective (clustering) behavior, synchronization or desynchronization, and time variability has been reported. In such cases, and given the kinds of phenomenon to be studied, there is an increasing need for powerful techniques that can infer the time-varying dynamics of the oscillatory networks.
We introduce a new method that encompasses time-variability and reconstructs the inter-oscillator coupled dynamics [1]. Based on Bayesian inference for stochastic differential equations (SDE), the technique infers the multivariate dynamics of interacting oscillators. The Bayesian probability lying at the core of the method is itself time-dependent via the prior probability as a time-dependent informational process. By considering complex interacting systems that are oscillatory and subject to noise, the method extracts their dynamical properties and functional relationships. We generalize the method to encompass networks of interacting oscillators and demonstrate its applicability to small-scale networks [2].
By reconstructing the phase dynamics in terms of a set of periodic base functions, we applied the method on numerical examples to determine the time-variability of structural and functional connectivity within the networks. We considered pair-wise and joint coupling relationships. Our analysis showed that when one applies appropriate surrogate testing, the technique is able to distinguish the structural couplings as being significant, thus differentiating from what are considered to be effective couplings. We showed that the method is readily applicable in situations when the dynamical variations are taking the network structure through various different connectivity states, and that the different topologies are detected reliably throughout their time evolution.

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CT8: Delayed systems

Stochastic delay equations: Numerical methods for biophysical models

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Recent work has shown that models of human balance control and postural sway must incorporate noise and time delays in order to accurately explain observed data [1]. To examine the interplay between these phenomena, researchers have studied systems such as

$$dX_t = \alpha X_{t-\tau} dt + dW_t, \tag{1}$$

a stochastic delay equation, where W_t denotes standard Brownian motion. In such studies, it is typical to compute numerous sample paths of Eq. 1 using Monte Carlo techniques, in order to calculate quantities of interest such as the distribution of X_t for $t > 0$. For a stochastic equation with no time delay, this distribution could be computed by solving the associated Fokker-Planck equation; however, the Fokker-Planck equation associated with stochastic delay equations is circular and has thus far been of limited use in numerical solution procedures.
Here we present two numerical methods for computing the distribution of the solution X_t of Eq. 1 without resorting to Monte Carlo simulation. Our strategy consists of discretizing the equation both in time and in probability space, i.e., converting all random variables in the problem from continuous to discrete. This yields a delayed random walk, the probability mass function of which can be computed using either a recursive method or a tree method. The recursive method involves unraveling the time-discretization of Eq. 1 into a sum of random variables, and then computing the distribution of this sum. The tree method consists of incrementally growing a tree of all possible sample paths of Eq. 1 together with the respective probabilities along each path. Rather than grow full trees [2], we grow approximate trees in which paths that differ by a small tolerance are allowed to coalesce. Both methods we propose can be used to solve Eq. 1 even if W_t is replaced by a different stochastic process, e.g., Poisson noise.
We analyze the accuracy and efficiency of the two competing numerical methods, and we judge which method can be more readily generalized to solve a more complex stochastic delay model that incorporates feedback control [3]. Due to its discontinuous nature, this latter model cannot be treated using standard numerical methods for stochastic delay differential equations [4].

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Spectrum and amplitude equations for scalar delay-differential equations with large delay

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We study scalar delay-differential equations

$$\frac{dx}{dt} = f(x(t), x(t-\tau)) \tag{1}$$

with long delay. Firstly, we describe the asymptotic properties of the spectrum of linear equations

$$\frac{dx}{dt} = ax + bx(t-\tau). \tag{2}$$

Using these properties, we classify possible types of destabilization of steady states. In the limit of large delay, this classification is similar to the one for parabolic partial differential equations. We present a derivation and error estimates for amplitude equations, which describe the local behavior of delay-differential systems close to the destabilization threshold.

Reservoir Computing with a single nonlinear node subject to multiple delay feedbacks

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Reservoir Computing (RC) is a new neuron-inspired research line in machine learning. This approach yielded excellent results in many tasks such as time series prediction or speech recognition. Standard RC systems are drive-input networks of many nonlinear elements sparsely connected. The transient states of the nonlinear system induced by the input are used to compute. A key feature of RC systems is that they are able to remember previous inputs. This memory capacity of the system allows the processing of time varying data streams. The memory capacity of standard RC systems increases with the number of nonlinear elements, called neurons. Recently, a new way to implement RC has been presented within the framework of the European project PHOCUS (see http://www.ifisc.uib-csic.es/phocus/). In this new approach, the network of multiple nonlinear elements is substituted by a single nonlinear node with delayed feedback. This system can process information as efficiently as traditional RC and the reduction to a single node drastically facilitates hardware implementations. However, the memory capacity of a single nonlinear node subject to feedback is limited and tasks with high memory requirements remained unattainable hitherto. To increase the memory capacity of one single node we have added multiple delay lines that feed back several input responses simultaneously. We have performed numerical simulations to determine the performance of an Ikeda-type nonlinearity with such a multiple delay-feedback topology. The Ikeda nonlinearity is often found in electro-optical systems. The equation that governs our system is given by:

$$\dot{x}(t) = -x(t) + \beta \sin^2 \left[\gamma I(t) + \phi + \sum_{i=1}^{P} w_i x(t - \tau_i) \right], \tag{1}$$

with β the nonlinear feedback strength, γ the input scaling, ϕ the phase, $I(t)$ the input, w_i and τ_i the feedback weight and length and P the number of feedback lines. We have found that the memory capacity of the system can be increased as we increase the number of delay lines: the longer the length of the feedback line, the older the state of the system that is being fed back. We have also studied the performance of multiple delay configurations in two high demanding memory tasks that are considered standard benchmarks in the RC field, the NARMA-10 and the PARITY tasks. For both tasks, the single delay node with multiple delay lines not only outperformed the single delay node with only one delay line, but also the standard RC systems.

Synchronization of neuronal complex networks in the presence of delayed interactions

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In the study of complex systems, as important as the intrinsic properties of individual elements stands the network in which they are embedded and of which they acquire great part of its responsiveness and functionality. We have explored how delay and different topological properties of several classes of neuronal networks affect the capacity of their elements to establish well-defined temporal relations among the firing sequence of their action potentials. This capability of neuronal networks to produce and maintain a precise coordinated firing (either evoked by external drive or internally generated) is central to neural systems to exploit precise spike timing for the representation and communication of information. Our results, based on simulations of conductance-based model of neurons in an oscillatory regime, indicate that only certain network topologies are able of a coordinated firing at a local and long-range scale simultaneously. Besides network architecture, we find that delays not only set the phase difference between the oscillatory activity of remote neural populations but determine whether they can set in any coherent firing at all. We have also investigated how inhomogeneities in natural firing frequencies across neurons affect the synchronization of the network.
Another important aspect is the study of functional networks in complex systems. These networks are obtained from the analysis of the temporal activity of their components, and are often used to infer their unknown underlying connectivity. We have obtained the equations relating topology and function in a system of diffusively delay-coupled elements in complex networks. We have solved them exactly in motifs (directed structures of three nodes), and in directed networks. The mean-field solution for directed uncorrelated networks shows that the in-degree of the nodes plays a dominant role in the clusterization of the activity, and that the locking frequency decreases with increasing average degree. We found that the exponent of a power law degree distribution of the structural topology, γ, is related to the exponent of the associated functional network as $\alpha = (2-\gamma)^{-1}$, for $\gamma < 2$. We have also proposed a mean-field theory for uncorrelated random networks that proves to be pretty accurate to predict phase synchronization in real topologies, as for example the C.elegans or the Autonomous Systems connectivity.

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CANCELLED. ~~Frequency discontinuity in the globally coupled oscillators with delay~~

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We consider an ensemble of globally coupled Kuramoto or Landau-Stuart oscillators with delayed interaction and obtain a general equation for the frequency of synchronized dynamics in the network for the different phase behaviors. When the number of oscillators is increased, the frequency of in-phase synchronized motion remains unaffected while the anti-phase solutions either disappear or give clustered phases, depending upon the parameter values. Consequently two kinds of transitions are possible when the delay parameter is varied: (i) a discontinuity in the frequency with a transition from in-phase to in-phase dynamics, and (ii) a transition from from in-phase motion to a clustered phase with a frequency discontinuity.

CT9: Fluids and granular media

Model of a two-dimensional extended chaotic system: Evidence of diffusing dissipative solitons

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We investigate a two-dimensional extended system showing chaotic and localized structures. We demonstrate the robust and stable existence of two types of exploding dissipative solitons. We show that the center of mass of asymmetric dissipative solitons undergoes a random walk despite the deterministic character of the underlying model. Since dissipative solitons are stable in two-dimensional systems we conjecture that our predictions can be tested in systems as diverse as nonlinear optics, parametric excitation of granular media and clay suspensions and sheared electroconvection. In addition, we describe the stable existence of quasi one-dimensional solutions of the two-dimensional cubic-quintic complex Ginzburg-Landau equation for a large range of the bifurcation parameter. Quasi one-dimensional (quasi-1 D) denotes in the present context solutions of fixed shape in one spatial dimension being simultaneously fully extended and space-filling in the second direction. This class of stable solutions arises for parameter values for which simultaneously other classes of solutions are at least locally stable: the zero solution, 2 D fixed shape dissipative solitons or 2 D azimuthally symmetric or asymmetric exploding dissipative solitons. We show that quasi-1 D solutions can form stable compound states with 2 D stationary dissipative solitons or with azimuthally symmetric exploding dissipative solitons, respectively. We also find stable breathing quasi-1 D solutions near the transition to collapse. The analogy of several features of the work presented here to recent experimental results on convection is elucidated.

Nonlinear dynamics in experimental devices with compressed/expanded surfactant monolayers

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The dynamics of surfactant monolayers are relevant in a wide variety of scientific and technological fields including medicine, pharmacology,material science, and nanotechnology. A common experimental set up to measure surface properties is a shallow liquid layer that is slowly compressed/expanded in a periodic fashion by moving two slightly immersed solid barriers, which varies the free surface area and thus the surfactant concentration. The forcing frequency is quite small, intending spatially uniform surfactant concentration, which allows for ignoring the fluid dynamics in the bulk. This approximation provides good results only if the dynamics is sufficiently slow. Here we present a long wave theory for not so slow oscillations, taking the fluid dynamics and the symmetries of the problem into account. This theory provides an asymptotic model that consists in a nonlinear diffusion equation that show fairly interesting nonlinear dynamics. Also, it uncovers the physical mechanisms involved in the surfactant behavior and allows for extracting more information from each experimental run.

Photoisomerization front propagation in dye doped liquid crystal submitted to a Gaussian forcing

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Lately photoresponse of materials has become a very attractive research subject. It offers ways to develop many applications without using an electrical power supply [1]. Many studies have shown a particular interest on the photoisomerization transition (between an anisotropic state and an isotropic state) which is used like an optical switching [2]. However these studies consider a homogeneous optical forcing [2, 3], while the optical external forcing is a laser beam with a Gaussian spatial profile. They have also showed that the temperature is an important factor for this transition.
We propose to study experimentally the front propagation in 2D submitted to a Gaussian profile corresponding to a photoisomerization. We will also compare also the front propagation with the spatio-temporal temperature evolution induced by the laser beam in the medium.
The setup is composed by a dye doped liquid crystal illuminated by a laser beam. The optical signal is recorded by a CDD camera. A polarizer is disposed in front of it to optimize the contrast between two states. In order to record the temperature evolution, a thermal camera is placed at a certain angle near the liquid crystal sample.
We determine experimentally that the transition is a first order with a hysteresis cycle. A bistable system submitted to a Gaussian forcing in 1D was studied theoretically by [4]. They find the front temporal evolution can be reproduced by a hyperbolic tangent. In the first place, to verify that the front propagation dynamics in 2D follows a hyperbolic tangente, we detect the circle radius in the time (the front position). The experimental result is in a very good agreement with the analytical trajectory. Later, we study experimentally and numerically the final front position with different laser intensities. The numerical simulations show a good quantitative correspondence with the analytical prediction and the experimental work also show a good qualitative correspondence with the analytical prediction.
Finally, we follow, in real time, the front propagation and the spatio-temporal evolution of the temperature in the dye doped liquid crystal. We show that there is a perfect correlation between the front and temperature propagations.

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New standing solitary waves in water

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By means of the parametric excitation of water waves in a Hele-Shaw cell, we report the existence of two new types of highly localized, standing surface waves of large amplitude. They are, respectively, of odd and even symmetry. Both standing waves oscillate subharmonically with the forcing frequency. The two-dimensional even pattern presents a certain similarity in the shape with the 3D axisymmetric oscillon originally recognized at the surface of a vertically vibrated layer of brass beads. The stable, 2D odd standing wave has never been observed before in any media.

Shear induced alignment of elongated macroscopic particles

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Shear induced ordering and alignment of elongated objects can be observed at all length scales in nature, in log jams on rivers, in seeds, nanorods, viruses, and even at molecular scales in nematic liquid crystals. For macroscopic particles these alignment processes are poorly characterized, despite their importance in agriculture or in industry. We showed that in steady shear the time and ensemble averaged direction of the main axis of the particles encloses a small angle with the streamlines. This shear alignment angle is independent of the applied shear rate across three decades, and it decreases with increasing grain aspect ratio. We also measured a considerable reduction of the effective friction due to the alignment. At the grain level the steady state is characterized by a net rotation of the particles, as dictated by the shear flow. Furthermore, we studied the evolution of the ordering process with different initial conditions.

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CT10: Quantum and hamiltonian systems

Information and energy exchange in multidimensional chaotic Hamiltonian systems

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In this talk I will discuss about some novel, recently obtained, results that relate information, energy exchange and sensibility to initial conditions on chaotic multidimensional Hamiltonian systems [1, 2]. Considering the degrees of freedom of the Hamiltonian as nodes of a complex dynamical network, I will discuss about the relation among the Mutual Information Rate (MIR), the Kolmogorov - Sinai entropy, the maximal Lyapunov exponent, and significant upper bounds of the MIR calculated in this network with these same quantities defined on bi-dimensional projections [3], as the energy of the system increases. I will also present some new formulae that connect information with energy. They show that the transfer of kinetic energy per time unit is an exponential function of the largest Lyapunov exponent of the network or an exponential function of the upper bound for the transfer of information per time unit. Therefore, energy is transferred along the most unstable direction of the Hamiltonian system and the amount transferred is larger the more chaotic the system is. Another relevant output of our results is that this complicate relationship among these many dynamical invariants can be established on bi-dimensional projections like for example on the kinetic versus potential plane. However, this relationship governs the behavior of the higher dimensional Hamiltonian system.

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Quantum dynamics: From coarse graining to a tower of scales via multiresolution

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We present a family of methods which can describe complex behaviour in quantum ensembles. We demonstrate the creation of nontrivial (meta) stable states (patterns), localized, chaotic, entangled or decoherent, from the basic localized modes in various collective models arising from the quantum hierarchy described by Wigner-like equations. The advantages of such an approach are as follows: i) the natural realization of localized states in any proper functional realization of (Hilbert) space of states, ii) the representation of hidden symmetry of a chosen realization of the functional model describes the (whole) spectrum of possible states via the so-called multiresolution decomposition. Effects we are interested in are as follows: 1) a hierarchy of internal/hidden scales (time, space, phase space); 2) non-perturbative multiscales: from slow to fast contributions, from the coarser to the finer level of resolution/decomposition; 3) the coexistence of the levels of hierarchy of multiscale dynamics with transitions between scales; 4) the realization of the key features of the complex quantum world such as the existence of chaotic and/or entangled states with possible destruction in "open/dissipative" regimes due to interactions with quantum/classical environment and transition to decoherent states. The numerical simulation demonstrates the formation of various (meta) stable patterns or orbits generated by internal hidden symmetry from generic high-localized fundamental modes. In addition, we can control the type of behaviour on the pure algebraic level by means of properly reduced algebraic systems (generalized dispersion relations).

Experimental observation of resonance assisted tunneling in systems with a mixed phase space

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In quantum mechanical billiards with a mixed phase space tunnelling from regular islands to the chaotic sea can be strongly increased by resonance-assisted tunnelling [1, 2]. This occurs due to nonlinear resonances, which cause different regular states to be close in energy. To experimentally verify this theory we designed a cosine-shaped microwave resonator with suitably placed absorbers destroying the resonances of the chaotic sea but not affecting the stable island. Then the tunnelling rate can be determined via the width of the resonances. Our experimental results are in agreement with theoretical predictions.

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Quantization of the strongly chaotic billiards near cosmological singularities of the gravitational field

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Close to a cosmological singularity, the most relevant pure gravity and supergravity theories in four to eleven spacetime dimensions admit a strongly chaotic cosmological billiard description. Such spacetime singularities are known to generically appear in classical gravitational theories based on general relativity, and they are expected to be resolved through quantum effects. The quantum analysis of the classical structure of these singularities reveals insights into how the promotion of the gravity theory to a quantum theory of gravity could be achieved. The quantization of the arithmetic billiard systems via the supersymmetry constraint leads to wavefunctions which are automorphic under generalized modular groups. For instance, the cosmological billiard domain for eleven-dimensional supergravity is given by the Weyl chamber of the hyperbolic Kac-Moody group E_{10}, and its associated "wavefunction of the universe" has to be an odd Maass waveform automorphic under the generalized modular group with respect to octonions. The new arithmetic perspective provides interesting implications for old issues in quantum cosmology, such as the quantum mechanical resolution of singularities, the arrow of time, ordering ambiguities, and it might yield new insights concerning the existence of infinitely many observables and the emergence of spacetime from pregeometric concepts. The exact analytic determination of the automorphic forms associated with the classically strongly chaotic billiards as of today is out of reach. Knowledge about the shape and volume of the billiard domains is essential for the application of semiclassical quantization methods to the classically chaotic dynamics. We investigate the evolution of generic initially localized relativistic wavepackets as quantum cosmological billiards towards the singularity, both in flat and in hyperbolic space description, and elucidate and illustrate the subtle and interesting special features of the wavepacket evolution in both cases [1, 2, 3, 4].

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Comparison of Newtonian and relativistic dynamical predictions for low-speed and low-speed weak-gravity systems

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It is conventionally believed that the special-relativistic dynamical predictions for low-speed systems are well-approximated by the Newtonian predictions for the same parameters and initial conditions. Similarly, it is also conventionally believed that the general-relativistic dynamical predictions for low-speed weak-gravity systems are well-approximated by the Newtonian predictions. However, in this talk, I will show with a few simple nonlinear systems – periodically-delta-kicked particles and bouncing ball – that this expectation is not always true, not only for single trajectory predictions [1, 2, 3] but also for statistical predictions [4, 5] such as probability density, mean and variance of the trajectory, scattering probabilities and momentum diffusion. These findings suggest that the Newtonian predictions are not always empirically reliable as conventionally expected for low-speed and low-speed weak-gravity systems. Other ramifications of these findings will also be discussed.

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PT3: Plenary talk

Quantifying gene-circuit dynamics at the single-cell level

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Cellular processes rely on the coordinated activity of multiple genes and proteins linked together in regulatory circuits. Understanding cellular processes requires a global view of these circuits at the system level. In that scenario, theoretical models become an absolute necessity in order to comprehend cellular behavior. Since the experimental values of most model parameters are unknown, it is imperative to validate the models by performing a quantitative comparison between experiments and theory. Here we show how such a comparison can be undertaken in a systematic way, using bacterial stress response as a case example. Our results also show how dynamics plays a crucial role in allowing for this quantitative approach to cellular physiology.

PT4: Plenary talk

Evolution on genotype networks leads to phenotypic entrapment

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The relationship between genotype and phenotype is many-to-many. In particular, genotypes encoding a particular phenotype form vast, connected networks that often span the whole space of possible genotypes. Regarding their topological properties, genotype networks are highly heterogeneous in degree and, in most know cases, assortative (as in RNA and proteins). These properties have important effects on the dynamics of populations evolving on genotype networks. In this contribution we demonstrate that, as time elapses, the probability that a population visits nodes of increasingly higher degree augments. In evolutionary terms, this implies that the probability that a population changes phenotype depends in a non-trivial way on the time the population has maintained its current phenotype. We derive a mathematical theory that explicitly quantifies this phenotypic entrapment and explicitly shown the dependence on measurable quantities such as network size, mutation rate, or fitness of the phenotype. Numerical simulations of dynamics on RNA genotype networks are used to illustrate the phenomenon and the predictive power of the theory.

MS6: Collective behavior in networks of oscillators

Between complete synchronization and complete incoherence in large, heterogeneous systems of coupled phase oscillators there is a rich variety of collective behavior with different types of transitions in the dynamics of macroscopic observables. In this symposium we will present detailed numerical and analytical studies of this highly non-linear, non-equilibrium regime. The transition to synchronization is found to be non-universal, i.e. It depends crucially on the system details, the type of coupling, the shape of the frequency distribution, even if it is symmetric and unimodal, and the topology of the complex coupling network.

Organizers: *R. Toenjes and A.Torcini*

Extensive chaos and coherent dynamics in sparse networks

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The research concerning the existing relationship between the topology of a "chaotic" system and the number of active degrees of freedom started in 1982 by Ruelle has known recently some interesting evolution. In this talk I will report the last results concerning the link between topology and degree of chaoticity in complex (neural) networks. In particular, in sparse networks the number of active degrees of freedom, as measured by the Lyapunov spectrum, increases linearly with the number of nodes, suggesting that in such systems chaos is extensive as in usual system with diffusive coupling. Despite the fact that the dynamics in such networks cannot be interpreted as the juxtaposition of weakly interacting sub-networks, as in diffusively coupled systems. This (apparent) contradiction has so far not found any solution. Furthermore, I will show that in sparse networks a finite connectivity (of the order of a few tens) is sufficient to sustain a nontrivial macroscopic dynamics even in the thermodynamic limit.

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Synchronization transition in sparse random networks of identical phase oscillators

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We consider the transition to synchronization in sparse random networks of attractively coupled, identical phase oscillators. When normalized by the input degree, complete synchronization is always an absorbing state of the system. However, this state might not be reached from random initial conditions. Instead, it can co-exist with a stable state of complete desynchronization or partial synchronization. The mean degree of the sparse random network plays the role of a topological bifurcation parameter. The bifurcation diagram of the macroscopic order parameter, including unstable branches of partial synchronization, are obtained with the help of a linear control scheme. Our results have been published in [1].

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Nonuniversal transitions to synchrony in globally coupled phase oscillators

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Emergence of collective behavior (synchrony) in large groups of non-identical oscillators is of great interest because it occurs in a wide variety of significant applications. Many important features of this phenomenon can be recovered from a paradigmatic system of phase oscillators that are globally coupled with a phase lag (Sakaguchi-Kuramoto model). For this model we formulate a general bifurcation analysis framework based on a frequency dependent version of the Ott-Antonsen method, which allows for a universal description of possible synchronization transition scenarios for any given distribution of natural frequencies. We show that, contrary to common belief, for certain unimodal frequency distributions there appear unusual types of synchronization transitions, where synchrony can decay with increasing coupling, incoherence can regain stability for increasing coupling, or multistability between partially synchronized states and/or the incoherent state can appear.

Pulse coupling versus diffusive coupling in neural networks

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Two coupling schemes are typically invoked when networks of phase oscillators are investigated: (i) Kuramoto-like (including the various generalizations) that is based on (instantaneous) phase-differences between pairs of oscillators; (ii) pulse-coupling, where the (delayed) interaction follows the transit of one oscillator trough a given threshold. Similar collective phenomena have been observed in the two setups, but also important differences have so far emerged. The two schemes are mutually compared to identify the role and meaning of various ingredients (such as pulse width, inhibition vs. excitation, delay).

MS7: Localized structures of light in dissipative media I

In recent years considerable progress has been made in understanding the properties of nonlinear localized structures of light (often called optical solitons) in dissipative systems. Due to their unique diffraction properties, such dissipative media, has very promising applications in modern technology. The two mini-symposiums we propose involve theoretical and experimental talks by leading groups working in nonlinear optics and laser physics. The purpose of the two mini-symposiums to bring together contributions of researchers working on mathematical, physical, and technological aspects of localized structures, and thereby to present an overview of the state of art in the formation and the characterization of localized structures. The following topics related to the formation of localized structures in dissipative systems will be covered: PART I Broad area VCSELs with delayed feedback in cavity solitons Localization of exciton polaritons in microcavities Liquid crystal light-valve with optical feedback

Organizers: *M. Tlidi, K. Staliunas and K. Panajotov*

Delay induced instabilities of localized structures of light in optical systems

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Cavity solitons are localized spots of light in the transverse section of passive and active optical devices: broad area lasers and semiconductor cavities with external coherent pumping. Under certain conditions a drift instability can appear in these devices leading to a transverse motion of cavity solitons. Such motion in distributed dynamical systems of different nature can be induced by various effects, e.g., walk-off, convection, phase gradient, vorticity, finite relaxation times, the so-called Ising-Bloch transition, symmetry breaking due to off-axis feedback, or resonator detuning. Recently it was shown within the framework of the Swift-Hohenberg equation [1] that a drift instability leading to a spontaneous motion of localized structures in arbitrary direction can be induced by a delayed feedback term. More recently the appearance of nontrivial instabilities resulting in the formation of oscillons, soliton rings, labyrinth patterns, or moving structures was demonstrated in this system [2].
First, we study the effect of delayed feedback on the mobility properties of transverse cavity solitons in a broad area semiconductor microcavity. We present analytical and numerical analysis of the dependence of the drift instability threshold and on the feedback strength, feedback phase, and carrier relaxation time. In particular we demonstrate that due to finite carrier relaxation rate the delay induced drift instability can be suppressed to a certain extent. We give analytical estimation of the soliton velocity near the drift instability point which is in a good agreement with numerical results obtained using the full model equations.
Next, the effect of delayed optical feedback on the dynamics of cavity solitons in a broad area semiconductor laser with a saturable absorber is investigated theoretically. It is shown analytically that the threshold of delay induced drift instability can be considerably reduced in a laser with broad spectral bandwidth of the gain medium. Furthermore, it is demonstrated that depending on the feedback phase it is possible not only to destabilize cavity solitons via the delay induced drift instability but also to suppress another drift instability [3] related to the finite relaxation rates of the gain and absorber sections.

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Spatiotemporal chaotic localized state in liquid crystal light valve experiments with optical feedback.

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We study the existence, stability properties, and dynamical evolution of localized spatiotemporal chaos. We provide evidence of spatiotemporal chaotic localized structures in a liquid crystal light valve experiment with optical feedback. The observations are supported by numerical simulations of the Lifshitz model describing the system. This model exhibits coexistence between a uniform state and a spatiotemporal chaotic pattern, which emerge as the necessary ingredients to obtain localized spatiotemporal chaos. In addition, we propose a simple model, Nagumo-Kurampto model, that allows us to unveil the front interaction mechanism at the origin of the localized spatiotemporal chaotic structures.

Spatial patterns and cavity solitons in spatially rocked nonlinear optical systems

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When coupled systems of oscillators are submitted to almost-periodic perturbations in the form of a 1:1 resonant periodic carrier whose amplitude's sign alternates in space (so-called spatial rocking), pattern formation associated to sychronization emerges. These patterns differ however from the classic 1:1 resonance ones in that now the system's response is phase-bistable —like in the classic 2:1 parametric resonance. Thus spatial rocking is an alternative to parametric forcing and this is especially important in systems which are insensitive to the latter, like most nonlinear optical cavities. Spatial rocking in this case just consists of injecting a resonant signal whose amplitude's sign alternates across the transverse plane (e.g. by interference between two tilted waves). We will show both in the active case (laser-like) [1] and in the passive case (Kerr-like) [2] that phase-bistable patterns (such as phase domain walls, phase domains and labyrinths) as well as phase-bistable spatial solitons (both dark-ring and bright) are formed thanks to spatial rocking.

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Optical vortex self-assembly in liquid crystal media

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Optical vortices are singular points where the electromagnetic field goes to zero and around which the phase screws up as an n-armed spiral, with n the topological charge. In low-order Gauss-Laguerre beams a single optical vortex appears as a phase singularity on the axis of the beam propagation direction. Optical vortex beams attract a lot of attention for the exchange of angular momentum between light and matter and the realization of quantum computational schemes. Up to now, the generation of optical vortex beams has been mainly realized by using spiral phase plate or diffractive optical elements. Among these schemes, some lack in tunability while others exhibit efficiency problems. Another approach has been, recently, proposed, which relies on pre-imposed radial director orientation in nematic liquid crystal samples, so-called, q-plates [1]. This method provides both tunability and high efficiency, however, the liquid crystal alignment can cause some beam deformation and a consequent loss in the quality of the generated optical vortices.

We have recently proved a novel method for the creation of optical vortex beams, which relies on reconfigurable and optically addressable self-induction of vortex-like matter defects in a liquid crystal texture [2]. At this purpose we have realized a liquid crystal light-valve (LCLV) that is filled with a nematic liquid crystal with negative anisotropy; the contact interfaces are treated in order to provide a hometropic alignment of the liquid crystals. Due the photocondutive substrate of the LCLV, the effective voltage across the liquid crystal layer acquires a bell shaped profile: higher in the center of the illuminated area and able to overcome the critical voltage prior to reorientation [3]. As we employ a liquid crystal with negative anisotropy, the molecules tend to align perpendicularly to the electric field with a 2π degeneration in the reorientation direction, causing the formation of a topological defect in its configuration. This localized defect behaves as an optical spin-orbit coupler/converter and the vortex induction yields the robust generation of beams with orbital angular momentum. The same method is applied to create optical vortex lattices of arbitrary configuration. For circularly polarized input beams, vortex arrays with opposite topological charge are obtained, consistently with the spin-to-orbital angular momentum transfer. The closely packed distribution of matter defects ensures the parallel processing of large numbers of optical vortex beams, while the vortex arrangements is explained by simple topological arguments.

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MS8: Nonlinear dynamics in lasers: Fundamental Issues and Novel Applications II

Utilizing semiconductor laser dynamics for photonic information processing

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All-optical information processing has been a fascinating perspective for several decades, due to prospects of high data rates, energy efficiency and parallelism. The hopes, however, suffered from severe set-backs and the promises could not be fulfilled so far. New concepts, partly based on dynamical systems, have been renewing the hopes for photonic information processing. Recently, it has been demonstrated that delay-dynamical systems can be employed to implement reservoir computing, a powerful neuro-inspired machine learning concept [1]. This learning-based concept is based on the utilization of nonlinear transient responses of dynamical systems. In this contribution, we present the potential of a simple dynamical system, consisting of a single semiconductor laser with delayed optical feedback, to process information at Gigabyte per second data rates. We are able to successfully perform computationally hard tasks by injecting input information into the laser and analysing its transient responses. These tasks comprise classification, as well as time series prediction tasks [2]. We illustrate, how diverging from the digital paradigm towards nonlinear laser dynamics can enable energy-efficient and fast all-optical computing. We identify requirements for the delay-dynamical system and address how to tackle noise in this analog systems approach. Finally, the possibilities to go towards configurations of coupled lasers will be discussed.

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Two-mode dynamics of semiconductor lasers induced by optical injection and feedback

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We review the features of VCSEL nonlinear dynamics induced by optical injection and optical feedback that are due to the lack of polarization anisotropy and to multiple transverse mode operation. In case of optical injection we demonstrate a new Hopf bifurcation on a two-polarization-mode solution that delimits the injection locking region and a new resonance tongue for large positive detunings that is due to polarization switching and injection locking of first-order transverse mode [1, 2]. Next, we discuss how the presence of an excited state impacts the dynamics of an optically injected quantum-dot laser. Mapping of the bifurcations in the plane frequency detuning vs. injection strength shows that the relaxation rate scales the regions of locking and single- and double-period solutions [3]. Within the regions of time-periodic solutions, close to the saddle-node bifurcation boundary, dynamics resemble excitable pulses as a result of a bottleneck phenomenon [3]. The interpulse time follows an inverse square root scaling law as a function of the detuning. In the presence of noise, close to the locking region, the interpulse time follows a positively skewed normal distribution [3]. For the case of quantum dot laser lasing simultaneously from the ground and excited states and optical injected into the ground-state mode alone, we demonstrate the generation of regular picosecond pulses and pulse packages in the intensity of the excited-state mode [4]. We attribute this dynamics to an intrinsic gain switching mechanism where the relaxation time is modulated by the oscillations in the occupation of the ground and excited energy states. For the case of optical feedback in VCSELs [5] we show that for long and short external cavities the Lang-Kobayashi model is in good agreement with experiments on polarization switching, mode hopping and antiphase oscillatory dynamics at the delay time. These last dynamics modify polarization residence-time distribution making it oscillatory. We demonstrate numerically and experimentally coherence resonance in such bistable, time-delayed optical system. We present results on low frequency fluctuation and pulse-package dynamics in VCSELs and discuss the role of light polarization. We discuss polarization rotating OF for generating high frequency pulses as a result of EC mode beating.

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Nonlinear dynamics of quantum dot lasers under optical injection and feedback

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Self-organized semiconductor quantum-dot (QD) lasers are modelled using nonlinear rate equations with microscopically calculated carrier-carrier scattering processes between the carrier reservoir and ground and excited state confined QD levels. In particular, the complex dynamics and bifurcation scenarios of a QD laser subjected to delayed optical feedback or optical injection are investigated. Our simulations of optically injected QD lasers show that the complex bifurcation scenarios depend on the carrier lifetimes, which in turn alter the turn-on damping of the QD laser. Furthermore we find a pump current sensitivity of the frequency locking range which is directly related to the nonlinearity of the carrier lifetime. Coherence resonance is found in the excitable regime near the boundaries of the locking tongue and is related to a saddle-node infinite period (SNIPER) bifurcation. For the QD laser with optical feedback we study a five variable model, and consider the case of small linewidth enhancement factor and short external cavity. We determine the bifurcation diagram of the first three external cavity modes and analyze their bifurcations. The first Hopf bifurcation marks the critical feedback rate below which the laser is stable. We derive an analytical approximation for this critical feedback rate that is proportional to the damping rate of the relaxation oscillations and inversely proportional to the linewidth enhancement factor.

Coherence resonance in quantum-dot lasers with optical perturbations

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We discuss the noise induced effect of coherence resonance for quantum-dot(QD) lasers subjected to different optical perturbations. The counterintuitive effect of improving the regularity of a pulsating light output with increasing spontaneous emission noise is studied by means of the correlation time and the distribution of interspike intervals. For optically injected QD lasers close to the frequency locking boundary, our numeric as well as analytic results show noise-induced spiking occurring close to a saddle-node infinite period (SNIPER) bifurcation. With increasing noise strength the region where noise-induced spiking is found increases, while the locking region shrinks. Further it is shown that the complex microscopically motivated model for the carrier and field dynamics inside the laser can be reduced to a generic SNIPER model if it is operated close to the locking boundary. Additionally we study the effect of noise on a QD laser subjected to optical feedback from a short external cavity. Here, excitable behavior and coherence resonance is found close to a homoclinic bifurcation. In contrast to the SNIPER bifurcation, the phase space configuration in the homoclinic case allows to manipulate the excitability threshold, for example with the laser pump current. Thus, the noise strength at which coherence resonance, i.e. best regularity, is found may be manipulated, allowing to adjust and to switch the regularity of the spikes by changing the operation point of the laser.

MS9: Complex dynamics and applications in cardiac electrophysiology

In this minisymposium different perspectives related to complex cardiac dynamics will be presented and how the theories of dynamical systems can be applied to unveil their fundamental mechanisms. Experimental evidences of multidimensional alternans dynamics and the mathematical models able to reproduce these behaviors will be described. Temperature dependent nonlinear dynamics will be addressed both in terms of experimental evidences and mathematical modeling.

Organizers: *I. R. Cantalapiedra and J. Bragard*

Recent advances in mathematical modelling of cardiac tissue: A fractional step forward.

Alfonso Bueno-Orovio[1], *David Kay*[2], *Vicente Grau*[3], *Blanca Rodriguez*[4] *and Kevin Burrage*[5]

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Fractional spatial models have a long history in mathematical modeling in capturing the dynamics of particle motion and interaction in systems with complex connectivity patterns. In the context of cardiac tissue, the impact of this complexity on many aspects of electrical conduction remains unknown. However, its improved understanding is key to advance our present interpretation of cell-to-cell coupling, and how diffusive current flow modulates dispersion of repolarization in the intact and diseased heart. Here we propose fractional diffusion models, where the integer order of spatial derivatives is replaced by a non-integer order, as an alternative description to the macroscopic effects of this tissue complexity. We illustrate the methodology through its application to a variety of human and animal models of cardiac electrophysiology. Our findings indicate that electrotonic interactions at tissue level must be nonlocal in nature in order to explain a number of relevant characteristics of cardiac propagation, such as the shortening of the action potential duration along the pathway of activation, or the progressive modulation by premature beats of spatial patterns of dispersion of repolarization. Hence, our results suggest the use of fractional diffusion models as a powerful tool to understand the role of tissue structure in modulating cardiac electrophysiology. The proposed approach may have, as well, important implications in promoting our current interpretation on the many facets of non-locality in other research fields influenced by heterogeneous media.

Defibrillation mechanisms on a one-dimensional ring of cardiac tissue

Jean R. Bragard

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In this talk we compare quantitatively the efficiency of three different defibrillation protocols commonly used in commercial defibrillators. We have built a simplified one-dimensional dynamical model of cardiac tissue using the bidomain formulation that is the standard model for describing cardiac tissue. With this dynamical model, we have shown that biphasic defibrillators are significantly more efficient (about 25%) than the corresponding monophasic defibrillators. We identify that the increase in efficiency of the biphasic defibrillators is rooted in the higher proportion of excited tissue at high electric fields.

Alternans due to refractoriness in SR Ca release dynamics

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Alternans is a well-known cardiac pathology, in which the duration of the action potential (AP) alternates at consecutive beats. Due to its proarrhythmic effects it is important to understand the mechanisms underlying its genesis. Inside the cell, the sarcoplasmic reticulum (SR) keeps a high calcium concentration, that is liberated when calcium is introduced into the cell, in a process known as calcium induced calcium release (CICR). It has been amply studied the case where alternans appears due to a steep relationship between the duration of an action potential and the time elapsed since the end of the previous AP. However, now it is widely accepted that alternans often appears due to instabilities in the dynamics of intracellular calcium cycling (itself an important messenger for the contraction of the cell). This instability can be due to a steep relationship between the amount of calcium released to the cytosol, and the calcium loading of the sarcoplasmic reticulum (SR), but in some occasions cytosolic calcium alternans is observed without concurrent oscillations in the SR Ca content. This situation suggests an alternative mechanism related with a dysfunction in the dynamics of the ryanodine receptor (RyR2).
To investigate the effect of SR release refractoriness in the appearance of alternans we have considered two mathematical models of ventricular and atrial single cell. The appearance of calcium alternans was studied stimulating the cell at a constant rate, for different stimulation periods and values of the RyR2 recovery time from inactivation, activation and inactivation times. This allowed construction of two-dimensional maps depicting the beat-to-beat response as a function of RyR2 activation and inactivation. Subsequently, a numerical clamping protocol was used to determine whether SR calcium loading or RyR2 recovery from inactivation could account for the induction of calcium alternans. With this approach, slowing of RyR2 inactivation induced alternans caused by beat-to-beat alternation in the SR calcium load. Interestingly, slowing of RyR2 activation also induced alternations in both cytosolic calcium and SR calcium load, but they were now caused by alternation in the number of available RyR2s. Together, this allows identification of domains where SR calcium load or RyR2 refractoriness underlie the induction of calcium alternans. In the case of atrial miocite we find that slowing recovery from inactivation time of the RyR2 shows period doubling bifurcation. On one hand, a steep relation between sarcoplasmic reticulum (SR) load and calcium release makes regular calcium cycling unstable at high SR calcium load and/or fast pacing rates, in agreement with previous explanation when RyR2 inactivation is not important. On the other hand, we show that calcium release can also depend strongly on the number of RyR2 ready to open if an important number of RyR2s inactivate after the release. This gives rise to a steep nonlinear relation between the calcium release and the level of recovered RyR2, so that a small change in the latter produces big changes in calcium release.
A corollary of this study is that RyR2 refractoriness can be the cause of alternans even when alternation in SR calcium load is present. The calcium alternans might be obtained at fast stimulation rates without concurrent SR Ca content fluctuations. Changing the recovery time from inactivation of the RyR2 a transition from regular response to alternans was observed. This transition was found to be hysteretic, so for a given set of parameters different responses were observed. A slow RyR2 recovery from inactivation can give rise to SR release refractoriness, resulting in calcium alternans and can be the main nonlinearity behind alternans even when alternation in SR-Ca load is present.

Propagation of electrical activity in cardiac tissue; Experiment and theoretical validations for the study of spiral waves in the heart.

Flavio H Fenton[1], *Ding Xiong*[2] *and Elizabeth M Cherry*[3]

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Although the cable equation has been widely used to simulate the propagation of waves in excitable media such as neural and cardiac tissue, it is known that it fails to reproduce some experimentally observed phenomena accurately. One such example is discordant alternans (a period-2 rhythm arising from a period-doubling bifurcation) in tissue, for which simulations require extended tissues on the order of 10 cm or longer, whereas experiments can readily develop it in tissues as short as 2 cm long. Another example is that action potentials measured experimentally can vary in shape and duration within small distances on the order of 1 to 2 cm, whereas the smoothing effects of the diffusion term in simulations eliminate action potential heterogeneity over those distances. In this talk we will show experimental evidence of these two examples and propose a different form coupling in the cable equation that preserves important properties such as conduction speed and wavelength, yet recovers these previously un-captured experimental dynamics.

MS10: Dynamics of nonspherical particles in turbulent flows

The aim of the minisymposion is to bring together researchers who are addressing different aspects of this multi-faceted problem, such as tumbling and preferential alignment of non-spherical particles, reflecting gradient fluctuations in the turbulent flow.

Organizers: *M. Wilkinson and B. Mehlig*

Tumbling rates in turbulent and random flows

Kristian Gustavsson[1], *Jonas Einarsson*[2] *and Bernhard Mehlig*[3]

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The dynamics of turbulent aerosols (suspensions of particles in turbulent flows) is important for the understanding of key processes in the Natural Sciences and Technology (turbulent rain clouds, planet formation in circumstellar accretion disks, and fibre suspensions, to name but a few). In recent years our understanding of the dynamics of turbulent aerosols has increased substantially, by means of direct numerical simulations, and by model calculations - often based on idealised models of the underlying flow and of the interactions between the flow and the particles. The analysis of models of spherical particles moving subject to Stokes force in random flows (with the appropriate statistics) has contributed to our understanding of the fundamental mechanisms giving rise to spatial clustering and collisions between spherical point particles suspended in such flows. Less is known about the dynamics of asymmetrical, non-spherical particles, despite the fact that non-spherical particles are of interest in a wide range of contexts. For example, tumbling ice particles in turbulent clouds may play an important role in cloud-particle interactions. Dust grains in circumstellar accretion disks are not spherically symmetric and the relative orientation at which such grains collide may have important consequences for the outcome of the collision process. The competition between tumbling and rotational diffusion of non-spherical particles determines the rheology of fibrous suspensions. Singularities in the orientation field of non-spherical particles determine the orientational patterns of rheoscopic suspensions. Recently, the tumbling rate of small particles in turbulent flows was investigated experimentally and by means of direct numerical simulations. It was found that disks tumble, on average, at a much higher rate than rods, and this fact was related to the observation that rods tend to preferentially align with the vorticity of the flow. We have analysed the tumbling of small non-spherical particles in random flows with finite correlation length and time. We compute the orientational dynamics systematically in terms of a perturbation expansion in the Kubo number. This makes it possible to address the following questions. First, how and when do disks and rods tumble differently? How does the nature of the Lagrangian flow statistics influence the tumbling? What is the effect of inertia on the orientational dynamics of small particles? We compare the results to those of recent experimental and numerical studies of non-spherical particles tumbling in turbulent flows.

Spherical and triangular Ornstein-Uhlenbeck processes

Michael Wilkinson

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There is a vast literature on how small objects undergo diffusion when subjected to random forcing, but much less has been written about how an object rotates due to a random torque. There is a dimensionless parameter characterising this problem: the persistence angle β is the typical angle of rotation during the correlation time of the angular velocity. When β is small, the problem is simply diffusion on a sphere. But little is known about models with finite β, describing smooth random motion on a sphere. I will discuss the formulation and solution of the simplest model, which is a spherical Ornstein-Uhlenbech process. In two dimensions (circular motion) this is exactly solvable. When β is large, the solution has a surprising property, which is analogous to the phenomenon of 'superoscillations'. In three dimensions we obtain asymptotic solutions for large β which involve a solving a radial Shroedinger equation where the angular momentum quantum number j takes non-integer values. The case where $j = (\sqrt{17} - 1)/2$ turns out to be of particular significance. As well as discussing random tumbling of a single body, I will also mention some new results on the geometry of triangles formed by triplets of particles floating on the surface of a turbulent fluid. Exact results are obtained for a model described by diffusional processes. In other models a power-law distribution of angles is observed. This is explained using a extension of the concept of an Einstein relation. This talk reports joint work with Alain Pumir (ENS, Lyon) .

Orientation statistics of elongated particles in turbulent flows.

Alain Pumir[1] *and Michael Wilkinson*[2]

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I will discuss the alignment of small elongated particles in fully developed turbulent flows. Direct numerical simulations show that, while at short times, the rods, initially aligned at random in the flow, align with the eigen-direction of strain with the largest eigenvalue, at long times, the particles align preferentially with vorticity. To understand the origin of this surprising property, I will compare with the evolution obtained from a simpler model of random strain, whose correlations reproduce the correlations measured from direct numerical simulations. Contrary to the results obtained using the Navier-Stokes equations, a strong alignment of the elongated particles with the fastest stretching direction of the rate of strain tensor is observed. I will argue that, in turbulent flows, the strong correlation between the rod axis and the vorticity vector arises from similarities between the equations of motion governing the directions of the particles and the vorticity.

Orientation of axisymmetric particles in random flow

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We study the orientation dynamics of non-spherical rigid particles in random flows. The stationary probability density function of orientations is calculated analytically under the assumption that the random flow is Gaussian and has a short correlation time. Generalizations of these results are studied numerically.

MS11: Emergent dynamics in coupled oscillators

Self-emergent synchronization of coupled oscillators is central to a spectacular variety of natural systems, including flashing fireflies, pedestrians on bridges locking their gait, circadian clocks in the brain, cardiac pacemaker cells, superconducting Josephson junctions, and chemical oscillators. In addition to homogeneous states of synchrony, striking spatio-temporal patterns called chimera states, where coherent and incoherent oscillations coexist, can emerge in the presence of spatially nonuniform (nonlocal) coupling. Understanding the mechanisms underlying the emergence and dynamical properties of such collective dynamics of coupled oscillators is crucial to understanding their role in natural systems. Eventually, this understanding will help to design methods to control such collective dynamics, which is of great importance in physics, biology and neuro-science. In this mini-symposium, we discuss recent theoretical and experimental advances in self-emergent synchronization in a variety of systems ranging from coupled phase oscillators to coupled FitzHugh-Nagumo equations and populations of generic mechanical oscillators.

Organizers: *O. Omel'chenko and E. A. Martens*

When nonlocal coupling between oscillators becomes stronger: Patched synchrony or Multi-chimera states

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Systems of nonlocally coupled oscillators can exhibit complex spatio-temporal patterns, called chimera states, which consist of coexisting domains of spatially coherent (synchronized) and incoherent dynamics. We report on a novel form of these states, found in a widely used model of a limit-cycle oscillator if one goes beyond the limit of weak coupling typical for phase oscillators. Then patches of synchronized dynamics appear within the incoherent domain giving rise to a multi-chimera state. We find that, depending on the coupling strength and range, different multi-chimeras arise in a transition from classical chimera states. The additional spatial modulation is due to strong coupling interaction and thus cannot be observed in simple phase-oscillator models.

The Kuramoto model with distributed shear

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We present a solvable phase model that generalizes the popular Kuramoto model. As starting point, we consider the mean-field complex Ginzburg-Landau equation with disorder

$$\dot{z}_j = z_j \left[1 + \mathrm{i}(\omega_j + q_j) - (1 + \mathrm{i}q_j)|z_j|^2\right] + \frac{K}{N}\sum_{k=1}^{N}(z_k - z_j), \tag{1}$$

where $z_j = \varrho_j \mathrm{e}^{\mathrm{i}\theta_j}$, and $j = 1, \ldots, N \gg 1$. Here, ω_j is the natural frequency of the j-th oscillator, whereas q_j is the so-called shear (or nonisochronicity) that quantifies the dependence of the oscillation frequency on the amplitude.
Under the assumptions that the coupling is purely diffusive (K real) and weak ($|K|$ small), a phase reduction of Eq. (1) yields [1]:

$$\dot{\theta}_j = \omega_j + Kq_j + \frac{K}{N}\sum_{k=1}^{N}\left[\sin(\theta_k - \theta_j) - q_j\cos(\theta_k - \theta_j)\right]. \tag{2}$$

We analyze this model in depth. Notice that if the oscillators are fully isochronous ($q_j = 0$) Eq. (2) becomes the standard Kuramoto model [1], and moreover the so-called Sakaguchi-Kuramoto model [2] is recovered if shears are nonzero and equal $q_j = q$.
We first assume ω and q are independently distributed, and hence the joint probability density function factorizes: $p(\omega, q) = g(\omega)h(q)$. For g and h Lorentzian, Gaussian or Laplace distributions, we get explicit analytical results [3, 4].
Our main finding is that if the shear diversity exceeds a certain threshold then the incoherent state is stable for all K. In particular if h is centered at zero, incoherence is always stable for

$$h(0) < \frac{1}{\pi} \tag{3}$$

In other words, the distribution of shears should be narrow enough in order to observe the usual (Kuramoto) transition from incoherence to synchronization.
We finally discuss the effect of assuming a statistical dependence between ω and q [5]: $p(\omega, q) = g_c(\omega|q)h(q)$.

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Chimera States - how mythological monsters from mathematics arise in the real world

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Since Christiaan Huygens' serendipitous discovery [1], self-emergent synchronization has been established as a striking manifestation of self-organization that nature employs to orchestrate essential processes of life. About ten years ago, a peculiar collective state was predicted by Kuramoto and his co-workers [3]: they studied a network of nonlocally coupled oscillators i.e. oscillators that are coupled with a strength attenuating with distance, and discovered a state where synchronous and asynchronous oscillators co-exist, even though the oscillators are identical. Due to its incongruous nature, this surprising phenomenon was later dubbed a chimera state, alluding to the ancient Greek monster with the same name. Since then, numerous theoretical studies have been carried out to study its stability properties and its emergence in various oscillator systems. Here, we use a purely mechanical system of coupled metronomes, swings and springs to demonstrate that chimeras emerge naturally from a competition between two antagonistic synchronization patterns [2]. Our setup mimics the topology studied previously [4, 5] with two weakly coupled oscillator populations, where the coupling strength within each population is stronger than with the neighboring population (thus constituting simplest discrete form of nonlocal coupling). By variation of the oscillation frequency and the inter-population coupling strength, we establish a phase diagram for chimeras, which encompass and extend the set of previously described states. Our experiments, by virtue of being a generalization of Huygens' classical setup, carve a fundamental link between the origins of synchronization and chimera states, where additional degrees of freedom create a tapestry of rich collective behavior. We furthermore present a mechanical model of our setup and, if time permits, discuss how we establish a mathematical link between a physical model exhibiting chimeras to the generic and simplest theoretical chimera model originally introduced by Abrams et al. [4, 5], paving the way to an interpretation of chimera states in a physical context [6]. We briefly explore how our system parallels with real world settings, ranging from power grids over neural oscillator networks to optomechanical arrays.

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Synchronization and dynamical differentiation in small networks of chaotic electrochemical oscillators

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We performed experiments with a small network of resistively coupled electrochemical oscillators to characterize relationships between the observed collective dynamics and the underlying topology of the network. Small networks were made using 2-20 electrodes that are connected in some preselected coupling topology with at most 150 connections. The nickel electrodissolution reaction on the electrodes generates phase coherent chaotic current oscillations. The small networks exhibited transitions to identical synchronization at different overall critical coupling strengths. The critical coupling strength (K_c) is compared to the predictions of the Wu-Chua conjecture that relates the K_c to the inverse of the absolute value of the second largest eigenvalue of the coupling matrix. At coupling strengths below identical synchronization, chaotic dynamical differentiation (clustering) can take place where the oscillators form groups of identically synchronized elements. The experiments revealed two important effects of network topology: (i) the clustering is often ‘fuzzy’: the elements tend to form diffuse groups and (ii) the importance of permutation symmetry on the pattern selection. Finally, we analyzed the capability of partial phase synchronization index based methodologies for deducing the topology in several weakly coupled networks. It is shown that these methodologies can successfully predict network topologies in three-locally coupled, in four ring, and four star coupled oscillatory networks in which the coupling strength is close to that required for emergence of phase synchrony. The presented experimental results indicate that the network theories provide a useful framework for the analysis of the dynamical response of the networked chemical reaction system.

MS12: Collective dynamics in living systems

Brief abstract describing the subject. Self-organization and collective behavior are key concepts to understand the emerging properties of biological systems. To explore the complex dynamics that arise spontaneously due to the interaction of the components in a group, scientists use an interdisciplinary approach that combines tools from nonlinear physics, molecular and cell biology, developmental biology and social sciences. In living systems, this coupling comes from intercellular interactions, morphogenetic signals, and environmental constraints. This mini-symposium explores the topic of collective dynamics from an interdisciplinary perspective and at different levels: from emerging mechanical properties in tissues (Xavier Trepat), differentiation and developmental systems (Saúl Ares), to collective behavior of cells (Kai Dierkes) and individuals in a population (Gonzalo G. De Polavieja).

Organizers: *D. G. Míguez and R. Guantes*

Forces and waves during tissue growth

Xavier Trepat

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A broad range of biological processes such as morphogenesis, tissue regeneration, and cancer invasion depend on the collective motion of cell groups. For a group of cells to migrate cohesively, it has long been suspected that each constituent cell must exert physical forces not only upon its extracellular matrix but also upon neighboring cells. I will present novel techniques to measure these distinct force components. Using these techniques, we unveiled an unexpectedly rich physical picture in which the distribution of physical forces is dominated by heterogeneity, cooperativity, and jamming. I will show, moreover, that these essential features of inter-cellular force transmission enable the propagation of a new type of mechanical wave during tissue growth. Finally, I will demonstrate that both in epithelial and endothelial cell sheets, forces and waves are mechanically linked to cell velocities through a newly discovered emergent mechanism of innately collective cell guidance: plithotaxis.

Collective animal behavior

Gonzalo de Polavieja

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I will describe the cognitive approach our lab is taking for the study of collective animal behavior. Our theory will be shown to correspond well to experimental data in ants, fish, birds and humans. I will also present extensions of the theory and new results obtained with our new tracking system that automatically follows individuals in a group without the need of marks on the animals.

Effects of coupling on sensory hair bundles

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Auditory signal detection relies on amplification to boost sound-induced vibrations within the inner ear. Active motility of sensory hair-cell bundles has been suggested to constitute a decisive component of this amplifier. The responsiveness of a single hair bundle to periodic stimulation, however, is limited by intrinsic fluctuations. We present theoretical and experimental results showing that elastic coupling of sensory hair bundles can enhance their sensitivity and frequency selectivity by an effective noise reduction.

Regulation of neuronal differentiation at the neurogenic wavefront

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Pattern formation is an essential part of embryonic development. As an organism develops, cells become distinct from each other creating robust patterns. Neurogenesis is an example of such a process in which individual cells single out to become neurons from a group of equivalent progenitor cells.
Pattern formation during neurogenesis has two features that strongly differ from those common in Physics pattern formation processes: it drives a spatially discrete fine-grained pattern (composed of two cell types) and it does not involve any transport of a chemical but just short-range cell-to-cell communication. In addition, pattern formation during neurogenesis often does not occur through pattern nucleation at different spatial locations or through spontaneous propagation over a less stable state. Instead, the neurogenic pattern grows regularly from a single expanding domain and its spreading is both externally and internally regulated. Pattern expansion requires a diffusing molecule (morphogen) that enables the dynamics of patterning to occur and whose production is, in turn, controlled by the pattern itself. Note that this morphogen is not involved itself in the pattern formation. This scenario is what we call a self-regulated wavefront.
How this propagation and the pattern left behind depend on the state of the invaded tissue? We have addressed this question combining both theory and experiments [1]. First, we have provided evidence of the molecular state of the invaded tissue in the vertebrate embryonic retina. Second, we have evaluated computationally the implications of such a state. To this end, we have modeled the neurogenic wavefront in terms of four variables: the morphogen, two variables that set the spatial interaction between cells, and a fourth variable that is a readout of the state of differentiation. Since this process is the result of biochemical interactions, we have extended our description to Langevin dynamics in which a multiplicative noise takes into account the intrinsic randomness of such reactions. Finally, we have also included the irregular shape and arrangement of cells in tissues.
Our results predict that certain change in the state of the invaded tissue from the normal wild type conditions, consistent with the mutation of a key gene, strongly alters pattern formation and wavefront propagation, frequently yielding irregular growing patterns. These results are consistent with previous experimental observations [2] and provide a potential explanation. Moreover, we have extended our conclusions to the context of neurogenesis in the fruit fly's eye, by first mimicking computationally experimental data previously reported [3].
Altogether, our work exemplifies the complexity of biological pattern formation and the benefit of using hybrid computational-experimental strategies.

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MS13: Spatio-temporal vegetation patterns in ecosystems

When ecosystems are subject to limiting resources such as water and nutrients, they adopt a periodic or localized distribution of densely vegetated areas and zones of bare soil. In order to combat drought, every plant struggles to spread their roots beyond the size of the aerial structure (crown) by an order of magnitude, for greater water uptake. However, this adaptation increases plant-to-plant competition between neighboring plants, and at plant communities level, via strong interaction, favour the formation of self-organized structures.

Organizers: *M. Tlidi and M. Clerc*

Bistability in savanna/forest systems

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We propose models taking into account tree postulation structure (saplings and adults), and the influence of fire and rainfalls to investigate the fact that in interface regions of savanna/forest a continuous transition is rarely observed: tree cover is either below 50% or above 75%. Fire is a main mediator of of this bistability phenomenon. We done improve on existing models for the savanana/forest interface in Africa to situation more adequate for South-American ecosystems.

A quantitative theory of vegetation patterns in arid landscapes

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When ecosystems are subject to limiting resources such as water and nutrients, they adopt a periodic [1] or aperiodic [2] distribution of densely vegetated areas and zones of bare soil. In order to combat drought, every plant struggles to spread their roots beyond the size of the aerial structure by an order of magnitude, for greater water uptake. However, this adaptation increases plant-to-plant competition between neighboring plants, and at plant communities level, via non-local interaction, favor the self-organization phenomenon [1]. Other modeling approaches that underlines either the role of water transport by below ground and above ground run-off [3], or the role of constructive influence of the environment randomness [4] have been proposed to explain the formation of vegetation patterns. In this communication, we present a theory of vegetation patterns that rests on two hypotheses: (i) the self-organization hypothesis that attributes their cause to interactions intrinsic to vegetation dynamics, (ii) the complementary self-assembly hypothesis that attributes their large spatial scale to the proximity of their dynamical conditions with a critical point. A non-local version of the F-KPP equation allows us to formulate these hypotheses in terms of individual plant properties [5]. Both general and parsimonious, this formulation is strictly quantitative. It only relies on structural parameters that can be measured with precision in the field. Quantitative interpretation of observations and of predictions provided by the theory are illustrated by an analysis of periodic patterns found in some Sub-Sahelian regions [5].

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Recent remote-sensing observations shed new light on broad scale vegetation patterns in drylands and raise new challenges for self-organization models

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Drylands at the interface between savannas or steppes and deserts have been recognized to frequently harbor conspicuous vegetation patterns displaying periodic spatial structures. Such patterns consisting of stripes, gaps and bands display very large wavelengths (often in the range 50 m to 150 m) compared to the size of the above-ground part of the individual constitutive plants, which is metric or infra-metric. Several classes of self-organization models have demonstrated their ability to reproduce the emergence of such patterns based on local processes of vegetation growth and plant-resource interactions as well as to mimic the succession of pattern morphologies along gradients of limiting-resource scarcity. Yet, the agreement between simulated patterns and reality has often remained checked on qualitative bases with limited quantitative tests. The increasing availability of satellite-borne zenithal views of the earth and the concomitant increase in spatial resolution of the remote sensing data is an unprecedented opportunity to carry out broad scale tests about the quantitative congruence between models' predictions and real-world measurements. Thanks to ancient aerial photos or declassified satellite images, historical series can be built in many places over the last sixty years thereby enabling comparisons between change in pattern morphology and climate variations. Recent studies conducted by our group shed new light on aspects of periodic spatial patterning as diverse as worldwide distributions of patterns, influence of drought on band migrations and wavelength changes along geographical or diachronic dryness gradients. Some of those results question the published self-organization models devoted to the question. Notably, observations in Sudan established that the shift from gapped to spotted patterns along a regional aridity gradient may be accompanied by an increase in pattern wavelength by a ratio as high as 1.7 [1]. We believe that accounting for so strong an increase raises a significant challenge to all models. In the present talk we will thus evoke the way in which the class of models based on plant structure and the non-local F–KPP equation [2] may in the future help accounting for such field observations.

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Strong interaction between plants induces circular barren patches: fairy circles

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Vast landscapes extending from southern Angola, Namibia, and South Africa exhibit localized barren patches of vegetation called fairy circles. They consist of isolated or randomly distributed circular areas devoid of any vegetation. They are surrounded by fringes of tall grasses and are embedded in a sparse grassland on sandy soils. When the aridity increases, the size of the fairy circles increases and can reach diameters up to 10 m. Although several hypotheses have been proposed, the origin of this phenomenon remains unsolved. We show that a simple non-local model of plant ecology based on realistic assumptions provides a quantitative explanation of this phenomenon. Fairy circles result from strong interaction between interfaces connecting two uniform covers: the uniform grassland and the bare states, and their stabilisation is attributed to the Lorentzian-like non-local coupling that models the competition between plants. The cause of their formation in thus rather inherent to the vegetation dynamics. Our analysis explain how a circular shape and fringes are formed, and how the aridity level influences the size of the fairy circles. In agreement with field observation, these theoretical findings, provide a link between a strong non-local interaction of plants and the formation of stable fairy circles. Finally, we show that the proposed mechanism is model-independent: indeed, it also applies to the reaction-diffusion type of model that emphasizes the influence of water transport on the vegetation dynamics.

MS14: Quantum-chaotic dynamics: Theory and experiment

During the last two decades, there has been much interest in the experimental realization of relatively simple quantum systems whose classical counterparts are nonintegrable and chaotic. These systems are now known to exhibit a rich variety of quantum-dynamical phenomena, such as dynamical localization, quantum resonance, quantum accelerator modes, and quantum ratchets, in a wide range of a scaled Planck constant. It is also well established that dynamical localization and related phenomena have interesting analogues in solid-state physics such as the Anderson localization and the Anderson metal-insulator transition. Several phenomena have been experimentally observed, mainly by using atom-optics techniques with cold atoms or Bose-Einstein condensates (BECs). This allowed to verify theoretical predictions and to simulate solid-state-physics phenomena by their quantum-chaotic analogues using cold atoms. Some phenomena, such as quantum accelerator modes, were originally discovered experimentally and later explained theoretically. Also, the experimental use of BECs motivated the study of quantum-chaotic dynamics on the basis of the nonlinear Schrödinger equation, exhibiting chaos by itself. The scope of this Minisymposium is to present and discuss a representative set of all the issues mentioned above and related topics.

Organizers: *I. Dana*

News from the (quantum) kicked rotor

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Despite its simplicity and its long-standing history of research, the quantum kicked rotor model continues to offer many interesting facets. Most of the relevant recent research has been triggered by experimental realisations of the model, which include important amendments. Here an overview over recent experimental results is given, backed by theoretical developments of the original model. The new aspects include all-optical realisations with perfect control over initial states, the engineering of phase space by phase control of the kicking potential, and last but not least a series of results close to the quantum resonances of the kicked rotor where ballistic transport is possible. In the latter regime, the system is very successfully described by a semi-classical theory [1] which eases new important predictions.

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(Quantum) chaos, disorder, and ultracold atoms

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Usual quantum mechanics is linear, hence sensitive dependence on initial conditions – and thus chaotic behavior – is not present in (one-particle) quantum systems. On the other hand, many-body quantum physics is extremely complex, although the underlying equations are still linear. Interesting things happen in the intermediate range of "mesoscopic" systems, like Bose-Einstein condensates (BECs). These are large (up to one million atoms) quantum-coherent, intricate systems, whose dynamics is qualitatively different from one-atom dynamics. It is particularly interesting that particle interactions in BECs can be modeled in an "easy" way, via a mean-field approximation that leads to a *nonlinear* equation, the so-called Gross-Pitaevskii equation. This approximation turns out to be a very good one in most experimental situations. In this talk I shall discuss simple situations putting into evidence the mesoscopic behavior of such systems. The nonlinearity due to the interactions may for example lead to genuine chaotic behavior due to sensitive dependence on initial conditions, called "quasi-classical" chaos. Another situation of interest is that of disordered quantum systems, modeled by the celebrated Anderson model, where the interplay of quantum interference and disorder produces a localization and freezing of the wavefunction, a highly non-intuitive behavior. Adding nonlinearity to this system generates a wealth of new behaviors which are far from being thoroughly understood at the present time. Ultracold atoms have become in recently a privileged tool for "quantum-simulating" complex quantum systems, both theoretically and experimentally. Such systems present many advantages. First, they exist at very low temperatures, where decoherence sources (collisions, spontaneous emission of photons. . .) can be controlled to a very high level. Second, the strength of particle-particle interactions can be controlled – and even suppressed – by the so-called Feschbach resonances. Thirdly, quantum probability distributions can be directly measured in such systems. These characteristics made ultracold atoms a paradigmatic system to realize "simple" models of complex systems.

Kicked rotor dynamics as a test system for Bose-Einstein condensate dynamical depletion

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The Gross-Pitaevskii equation is well-established as the canonical dynamical description of atomic Bose-Einstein condensates at zero-temperature, however the fact that this is a nonlinear equation combined with the presence of linear instabilities can lead to decoherence, or depletion of the condensate, which must necessarily be treated self-consistently. This is a generic issue, however we choose the BEC analog of the quantum delta-kicked rotor as a prototypical example of such a system. The dynamics are described within a second-order (in the non-condensate fluctuations), number-conserving description; these equations describe the coupled dynamics of the condensate and non-condensate fractions in a self-consistent manner, and correctly capture the phonon-like nature of excitations at low temperature, making them ideal for the study of low-temperature, non-equilibrium, driven systems.

Staggered ladder quasienergy spectra for generic quasimomentum

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A new kind of regular quasienergy (Floquet) spectrum is shown to be exhibited by the generalized kicked particle under quantum-resonance conditions for generic quasimomentum, a quantity most relevant in atom-optics experimental realizations of kicked-rotor systems. The new non-Poisson regular spectrum has the structure of a staggered ladder, i.e., it is the superposition of a finite number of ladder subspectra all having the same spacing, which is independent of the nonintegrability of the system. This spectral structure is found to have several quantum-dynamical manifestations: A suppression of quantum resonances, a novel type of dynamical localization, and traveling-wave components in the evolution of wavepackets. These phenomena are shown to be robust under small variations of the quasimomentum and should therefore be experimentally observable using Bose-Einstein condensates with small quasimomentum width.

MS15: Molecules in motion through phase space bottlenecks

A chemical reaction can be seen as the process in which reactants are transformed into products, after passing through a transition state (TS). This basic idea extends beyond chemistry to several other fields, such as celestial mechanics, e.g., objects may be captured by a planet after passing through a TS; stellar physics, where the rate of escape of stars from a cluster is regulated by a TS, and in nuclear physics. All of these seemingly disparate problems can be reconciled using methods developed in the context of Dynamical Systems Theory. The goal of this Minisymposium is to provide a forum for recent advances in the theory and application of TST to be discussed with a view to mapping out fruitful future research directions.

Organizers: *R. M. Benito and F. Borondo*

Detecting and analyzing methods of normally hyperbolic invariant manifolds

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Normally hyperbolic invariant manifolds (NHIMs) are well-known organizing centers of the dynamics in the phase space of a nonlinear system. Locating and analyzing such manifolds in systems far from symmetric or integrable, however, has been an outstanding challenge. Here we develop a detection method for codimension-one NHIMs and a method for analyzing the breakdown of the NHIMs. We demonstrate the two methods in a hydrogen atom in crossed electric and magnetic fields.

Stochastic transition states and reaction barriers

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The identification of trajectories that contribute to the reaction rate is the crucial dynamical ingredient in any classical chemical rate calculation. This problem often requires a full scale numerical simulation of the dynamics, in particular if the reactive system is exposed to the influence of a heat bath. Reactive trajectories can be identified much more easily if one knows the the invariant surfaces that separate reactive and nonreactive regions phase space. The location of these invariant manifolds depends both on time and on the realization of the driving force exerted by the bath. I will demonstrate how these invariant manifolds can be calculated and used in a formally exact reaction rate calculation based on perturbation theory for any multidimensional potential coupled to a noisy environment.

Including roaming trajectories within the TST fold

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The rates of chemical reactions (or any activated process) are by definition determined by the flux of reactants (or initial states) that end up as products (or final states). Through the last hundreds years of studies on reaction rate theory, it has become clear that this can be equated to the flux through any surface that divides reactants from products as long as only those trajectories that end up as products are included in the flux. Transition state theory (TST) ignores this last clause. It thereby overestimates the rate if any of the trajectories recross the dividing surface. However, its advantage is that it replaces a dynamical calculation with a geometric one. The recent identification of roaming trajectories, that persist for a long time as neither reactant or product without ever visiting near the col on the energy landscape, challenges the dogma that TST's only error lies in the omission of recrossing trajectories. We have investigated these dynamical and geometric structures in the case of the ketene reaction. We have constructed roaming trajectories that do indeed cause violations of the TST hypotheses when the choice of dividing surface lies within the phase space that is neither associated with reactant or product. However, appropriate choices of the dividing surface can incorporate the flux of the roaming trajectories without suffering recrossings. In this way, the existence of roaming trajectories are seen to impose a limitation on which dividing surfaces are appropriate for the calculation of either exact or approximate TST rates, but they do not unseat the existence of dividing surfaces that can safely be used to calculate rates.

Normal forms for the dynamics of a laser-driven chemical reaction

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The Transition Sate Theory allows to obtain kinetic information about molecular systems without knowing the whole Potential Energy Surface. It is based on the obtention of a dividing surface on the phase space. The equator of the dividing surface corresponds to the so called “activated complex”. Once it is known it makes possible to obtain the gap time distributions, the reactive density of states, or the reactive flux across it and so, to calculate reaction rates. Such a dividing surface can be calculated even if the Hamiltonian function depends on time. That fact enables us to include laser-pulse perturbations [1], and so to study its effect on the dynamics and kinetics of molecular systems.
Here we study the isomerization process for the molecular system LiNC/LiCN. A general way to write the Hamiltonian function is

$$H(R, \theta, p_R, p_\theta, t) = H_0(R, \theta, p_R, p_\theta) + R\xi(t)\cos\alpha,$$

where H_0 is the Hamiltonian of the LiNC/LiCN system R, θ are the Jacobi coordinates, p_R, p_θ are the conjugated momenta, α is the angle between the C-N and the pulse and ξ is the function that simulates the electromagnetic pulse. The mathematical equation that describes the pulse has been taken from [1], and it depends on some parameters such as the period of the perturbation, the amplitude or the frequency. The main goal of this study is to understand the influence of these parameters on the dynamical geometric objects near the dividing surface (transition state, normally hyperbolic invariant manifold and its stable and unstable manifolds) and on the kinetic data mentioned before.
In this presentation we will focus on the effects of the laser on the dynamics of H_0. A first effect is that the equilibrium saddle point disappears under the effect of the pulse, and it is replaced by a periodic time-dependent trajectory. The linearized dynamics around this trajectory shows that it is a saddle-like orbit. Then, we compute a high order normal form around this orbit and we use it to describe the dynamics nearby. This includes the effective computation of the relevant dynamical objects near the dividing surface.

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Poster session

P1 Normal form transformation explains effect of noise near Hopf bifurcation

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A nonlinear dynamical system can be transformed to a simpler and more symmetrical one which has the same qualitative dynamics in a neighborhood of a local bifurcation, using near-identity transformations. In particular by flattening the center manifold the transformation decouples slow dynamics on the center manifold from fast dynamics in the other variables, allowing to identify how noise introduced in the original equations will enter the slow dynamics. For arbitrary systems we derive the linear and non-linear transformations needed to bring a system to either semisimple or inner product normal form, including transformed noise terms, and automate this using Mathematica. The value of this approach is illustrated by application to neuroscience. In in a widely used dynamical model of cerebral cortex tissue (the Jansen-Rit model) the effect of noise direction in phase space on the oscillations close to a Hopf bifurcation is counterintuitive: the noise direction which causes the greatest phase diffusion and amplitude variance is almost perpendicular to the center eigenspace. Normal form reduction uncovers the reason for this, by showing how additive noise in the original 8-dimensional system manifests as additive and multiplicative noise in the 2-dimensional oscillatory dynamics on the center manifold.

P2 Chaotic dynamics in multidimensional transition states

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Many chemical reactions can be described as the crossing of an energetic barrier. This process is mediated by an invariant object in phase space. One can construct a normally hyperbolic invariant manifold (NHIM) of the reactive dynamical system that can be considered as the geometric representation of the transition state itself. It is an invariant sphere. The NHIM has invariant cylinders (reaction channels) attached to it. This invariant geometric structure survives as long as the invariant sphere is normally hyperbolic. We applied this theory to the hydrogen exchange reaction in three degrees of freedom. Energies high above the reaction threshold, the dynamics within the transition state becomes partially chaotic. We have found that the invariant sphere first ceases to be normally hyperbolic at fairly low energies. Surprisingly normal hyperbolicity is then restored and the invariant sphere remains normally hyperbolic even at very high energies [1].

[1] A. Allahem and T. Bartsch. *J. Chem. Phys* **137** 214310 (2012).

Parameter estimation in nonlinear models P3

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It is usually the case in the natural sciences that we face the problem of confronting our theories with real world data. This is a complicated endeavor and as models become more complex, there are severe limitations to what we can do in this regard. We should expect that in general, our models will not match the data; for a sufficiently complex system, it is very unlikely that we will ever come up with a perfect description. Also, there is noise in our measurements and we can only sample the world with finite resolution. This is a fundamental issue; we will not in general find parameters of our model such that there is a perfect match between data and model. Therefore, we are forced to ask for an estimation of our parameters.
In this work we are interested in estimating the parameters of arbitrary dynamical systems from experimental timeseries. Our method takes the cost function approach as a starting point. Ultimately, we propose criteria based on notions of algorithmic information theory and define an extended cost function to select the best parameters. Our approach poses an optimization problem for which there is no general solution and obtaining 'good' solutions ends up being strongly dependent on the particular situation at hand. The aim of our method is to provide a formalism that allows comparison of potentially good solutions and a rationale for picking the best solutions out of the many possible ones.
In order to test our procedure we perform numerical experiments on three systems; a linear oscillator, a chaotic oscillator (the Lorenz system) and a model for neural tissue performing computations on an external signal (forced additive model for neural populations firing rate). Recent works from Abarbanel et. al. and Ott et. al. allow for efficient approaches to the optimization task contained in our method and were found to be essential in its implementation. These techniques rely on the idea that if the model is good, its solutions will synchronize with the data [1, 2].
We show numerically that for the neural tissue model, our approach yields useful information and at the same time reveals that inspection of the cost function is misleading. This is taken to be as an existence proof of systems for which our approach turns out to be particularly good.

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P4 Nonlinear oscillations in birdsong

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Canary song is composed of highly stereotyped vocal units or sillables which are repeated to create phrases withing a song. The bird's vocal organ, the syrinx, is precisely driven by at least two physiological instructions; airsac pressure and the activity of a set of muscles [1]. Songbirds are emerging as a remarkable animal model to study how a brain reconfigures itself in order to acquire vocalizations which vary across seasons. For this reason, many of the controlling pathways have been thoroughly characterized by different groups in the past years. Accumulated experimental efforts together with the relative simplicity of avian brains allows for testing simple models with reasonable biophysical resemblance. In this work we focus on the respiratory patterns that drive the syrinx.
Previous work in the field of birdsong performed in zebra finches, suggest that the morphological features of pressure gestures are individually coded by local connections in nucleous RA and each of this gestures is sequentially activated by the High Vocal Center nucleous (HVC) [2].
In this work we put forward the hypothesis that the diversity of motor gestures in canaries can be explained by the nonlinear interaction of at least two timescales. In our view, different morphologies of these gestures correspond to different states of the network as a whole. To test our hypothesis we propose a simple generic model of neural populations driven by simple instructions. Due to nonlinearities, small parametric changes in the driving signal yield many possible coding strategies. Previous work by our group suggest that many morphological features could be explained by subharmonic responses of the driven neural substrate [3, 4]. Here, we present a quantitative approach to test our models against experimental data and support their plausibility.

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Dynamical features of interictal spikes in the human brain undergoing anesthesia P5

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We collected data from ECoG measurements (invasive electrocorticography) in epileptic human patients. These measurements are used by clinicians as part of a procedure prior the approval of surgery. Each electrode is placed on a grid over the exposed cortex and registers the synchronized activity of thousands of postsynaptic potentials. Since the procedure is invasive, the spatial resolution of this measurements is considerably higher than noninvasive EEG.
It is widely believed that there are pathological waveforms in these recordings which can be associated with epileptic seizures. Moreover, interictal spikes are used as a diagnostic tool for determining the spatial location of the seizure focus. The dynamical connection between interictal spikes and the onset of seizures remains elusive [1]. In this work we apply a nonlinear filter to detect interictal spikes in ECoG recordings. We find highly stereotyped waveforms with at least two timescales which occur when the subject is undergoing anesthesia. The occurrence of these events is highly correlated amongst sites on the grid.
As the subjects undergo anesthesia, several dynamical features of the recorded timeseries are affected. Previous work by our group and others suggest that the brain operates in a dynamically critical regime [2, 3]. Here, we perform a moving VAR analysis on our dataset and show that the spectral properties of the linear stability matrix change significantly. When the subject is awake, many modes are poised close to the instability. Finally, when the subject is unconscious, the system becomes more stable. This empirical evidence is consistent with the idea that dynamical systems capable of optimally performing computations should be poised at the critical regime [4].

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P6 Stochastic simulation of people moving in confined spaces

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The subject of our work is to study the behaviour of people trying to leave a confined space using some limited exits. In situations where panic took place, is it common to observe how this dynamic become extremely disorganized. Although such phenomena have many causes based in human nature, there are many other factors feasible to study by physical methods including computer simulations. Many people moving and interacting themselves together is an example of a highly complex system, and, this way cannot be modeled as a sum of independent movements of single persons. The interaction among particles, in this case people, is the main cause of the emergence of patterns that we are interested. We take as baseline the Brazilian norm of emergency exits in buildings, NBR 9077/2001 [1], in order to raise some questions about how the exits must be design in many different type of buildings such residential, commercial, educational and others. In order to simulate such problem we discretized the room in cells and use cellular automata under some rules in order to establish the dynamic. Basically we model people as particles trapped in a discretized container (i.e. a room) and the rules of movements are taken under the influence of a "field" created due the position of the exits and the walls. We study then, how the number, the disposition and the size of the exits affect the time necessary to take all the people out of the room. Supported by Capes, CNPq and Fapemig.

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Aging and memory maintenance: Tracking the evolution of functional networks P7

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Complex networks analysis has been one of the most active fields of science during the last decade. The structural and dynamical properties of networks and their applications to real systems have given a new viewpoint in the analysis of complex systems, with special advances in the understanding of social, biological and technological networks. Nevertheless, the main part of the literature focuses on static networks, i.e. on the characterization of specific, fixed networks. On the contrary, networks are in continuous evolution and their emergence, maintenance and extinction deserve the development of new network metrics able to capture their adaptability and plasticity. The main obstacle to carry out this kind of analysis is the absence of datasets that fully cover the evolution, from scratch, of a dynamical network. Interestingly, one of the most challenging complex systems that we are dealing with could be a good candidate to test this kind of analysis: the brain. Functional brain networks have been extensively analyzed from the perspective of Complex Networks Theory. When a certain cognitive process is carried out, functional networks obtained from the coordinated activity between brain sites emerge, and vanish after the cognitive task is finished. In the present work we analyze the evolution of functional networks during a certain memory task when an external interference is introduced. We measure the magnetoencephalographic (MEG) activity of a group of 26 healthy subjects, divided into 14 young and 12 old individuals. The MEG systems allows to record the cortical activity of 148 MEG scalp sensors during each memory task, which is divided into a period of memory fixation and a period of interference, where an external perturbation is applied. The recorded time series are split into 50 ms time windows. Next, we quantify the coordinated activity between brain sites (nodes) inside each temporal window with the phase-locking-value (PLV), a nonlinear measure of phase synchronization. This way we obtain a functional weighted network whose links' weights correspond to the PLV between nodes for each time window. These PLV networks, were compared to the baseline PLV networks and then, just positive increments were kept, and normalized to [0,1] interval, being 1 the highest increment in phase synchronization compared to the baseline. Finally, we analyze the evolution of the structure of the functional networks over time by measuring different network parameters such as the network strength, shortest path length, network clustering, outreach or efficiency. Interestingly, we detect clear differences between young and old groups, which are especially significant during the interference episodes. We track the evolution of the network and compare the results with the classical analysis of static networks, showing that this kind of analysis gives new information about functional brain organization and about the influence of aging into memory tasks.

P8 Collective almost synchronisation in complex networks

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This work introduces the phenomenon of Collective Almost Synchronisation (CAS) [1], which describes a universal way of how patterns can appear in complex networks for small coupling strengths. The CAS phenomenon appears due to the existence of an approximately constant local mean eld and is characterised by having nodes with trajectories evolving around periodic stable orbits. Common notion based on statistical knowledge would lead one to interpret the appearance of a local constant mean field as a consequence of the fact that the behaviour of each node is not correlated to the behaviours of the others. Contrary to this common notion, we show that various well known weaker forms of synchronisation (almost, time-lag, phase synchronisation, and generalised synchronisation) appear as a result of the onset of an almost constant local mean eld. If the memory is formed in a brain by minimising the coupling strength among neurons and maximising the number of possible patterns, then the CAS phenomenon is a plausible explanation for it.

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P9 From mono- to bi- modal self-sustained periodic oscillations: Nanoscale catalytic NO2 reduction

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Field Emission Microscopy (FEM) is a valuable method for studying the dynamics of catalytic reactions taking place on the surface of a nanosized metal tip acting as a catalyst. Local variations of the work function are reflected in the form of a brightness pattern in direct space and the surface composition of the sample can be qualitatively investigated during the ongoing catalytic process. Nanoscale resolution is achieved, providing a local analysis of the catalytic activity on single facets of the catalyst particle. Using this technique, we investigated the catalytic reduction of NO2 over a single platinum catalyst grain. The associated dynamics was monitored in real time via the brightness signal. Several nonlinear behaviors were observed, among which self-sustained periodic oscillations of water production were characterized by means of correlation analyses and attractor reconstruction from the time series. A transition to more complex oscillations was observed and characterized by the recurrence of a double peak in the brightness signal. The reconstructed attractor, Poincaré section and next maximum map extracted from the time series converge to indicate that the emergence of this second peak is due to a transition of the system from mono to bimodal periodic oscillations.

Contemporary tools for reducing the model error in weather and climate forecasting models P10

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Numerical weather prediction schemes are based on models that share the same fluid dynamics laws. Even the most elaborate state of the art models neglect numerous small scale processes and represent their influence on the larger scales by introduction of different parameters – parameterization of unresolved processes. Thus the existence of the so called model error, which is the difference between the physical reality (the atmosphere) and its representation by model, is inevitable. Contemporary tools for reducing model error in weather and climate forecasting models include empirical correction techniques. In this work we explore the use of such techniques on low-order atmospheric models. We first present an iterative linear regression method for model correction that works efficiently when the reference truth is sampled at large time intervals which is typical for real world applications. Furthermore we investigate two recently proposed empirical correction techniques on the paradigmatic Lorenz 1963 models with constant forcing while the reference truth is given by a Lorenz 1963 system driven with chaotic forcing. The estimation of the quality of prediction skill is based on calculation on anomaly correlation. Both methods indicate that the largest increase in predictability comes from correction terms that are close to the average value of the chaotic forcing.

Controlling the system with hyperbolic attractor P11

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For a long time it was a common opinion that hyperbolic attractors are artificial mathematical constructions [1]. However, in the recent papers [2, 3] there were proposed physically realizable systems that possess, in their phase space, the set with features that are very similar to hyperbolic type of attractors. As is known, invariant sets are called hyperbolic attractors of the dynamical system if they are closed, topologically transitive subsets, and every their trajectory possesses uniform hyperbolicity. Very familiar types of the hyperbolic attractors are Smale-Williams' solenoid and Plykin's attractor.
Further, it is well known that chaotic systems are very sensitive to the external perturbations. This property is used for controlling nonlinear systems and chaos suppression. Thus, an important question arises: Is it possible to suppress chaos in systems with hyperbolic attractors because these attractors are structurally stable subsets?
In the present contribution we study the possibility of stabilization of chaotic oscillations in systems with the Smale-Williams hyperbolic attractors by means of the Pyragas method with a delay [4]. It is shown that by means of external perturbation the dynamical system could be controllable: the hyperbolic attractor degenerates into a periodic one.

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P12 Determining functional and physical connectivity in complex time-series

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The study of the way information is exchanged between nodes in complex networks is of primordial importance for the understanding of its functionality. A quantity known as Mutual Information Rate (MIR), defined as the mutual information per unit of time, can quantify the exchange of information between nodes in a pair-wise fashion or between pairs of data sets, and is well defined for systems with correlation as well as memoryless systems. Our work utilizes the MIR and bounds for it to understand the relationship between information flow, functional and physical topology of complex dynamical networks. The bounds for the MIR in a network are defined in terms of dynamical invariants [1] such as Lyapunov exponents, expansion rates, dimensions, which consequently allows one to relate information with dynamical characteristics of this network, without needing to calculate probabilities, a challenge in time-series analysis. These invariants, easy to be calculated when the dynamical equations of the network are known, require huge efforts to be calculated in real data coming from complex systems. This work shows that using simple strategies, partitions that approximate the Markov generating partitions (whose probabilities densities of points belonging to them behave as if they had been generated by a random system) can be obtained. These dynamical invariants can be easily calculated from these approximate Markov partitions, which leads to the estimation of the bounds for the MIR. These Markov approximants can be also used to calculate the MIR, a quantity that differently from Shannon's entropy and mutual information, is well defined in systems with memory. This methodology is then used to determine functional and physical connections in data coming from complex and dynamical networks.

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Intermingled basins in coupled Lorenz systems P13

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We consider a system of two identical linearly coupled Lorenz oscillators, presenting synchronization of chaotic motion for a specified range of the coupling strength. We verify the existence of global synchronization and antisynchronization attractors with intermingled basins of attraction, such that the basin of one attractor is riddled with holes belonging to the basin of the other attractor and *vice versa*. Firstly, we show that the mathematical conditions for the existence of riddled basins are fulfilled, with the help of properties of finite-time largest transversal Lyapunov exponents and of the largest transversal exponent for particular periodic orbits. This is important as furnishes the sources of local transversal instability of the attractor even if stable in average. In a second place, we verify the existence of two scaling laws characterizing quantitatively the degree of uncertainty related to the riddled basins. These numerical results were compared to an analytical prediction, yielding a good accord where expected. Beyond the characterization of the structure of a riddled basin, these scaling laws allow to quantify the limitations to improve the ability in determining the final state of the system by increasing the accuracy level. In any case, for applications, multistability is already a source of troubles. Still worst, the existence of intermingled basins of attraction for the synchronized and antisynchronized chaotic states of this system jeopardizes the solution of the problem of ensuring a given final state, since the initial condition determination is always done within a certain uncertainty level. With riddled basins, any uncertainty level, however small, lead to complete indeterminacy of the future state of the system. Hence in this case we cannot use synchronization of chaos for any practical purpose, since we will always be haunted by the existence of the another, antisynchronized state, with a basin intermingled with the basin of the synchronized state. Of course, the same difficulties concern the predictability of natural phenomena modeled by coupled Lorenz systems. Therefore, the importance of detecting the regimes where riddling can occur in a dynamical system.

P14 Fermi acceleration in the annular billiard under magnetic field action

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In recent years, it have being reported that is possible to detect unlimited energy gain in several pulsating dynamic systems, and the LRA conjecture does also verified [1, 2, 3].
The annular billiard is a system comprised by two circular boundaries of different radius, they can be concentric or eccentric [4]. Particularly, the *electromagnetic breathing annular billiard* consists of the annular billiard that a time dependence is added on the length of each radius [1, 2] and the electric charged particle moves under the Electric and Magnetic external fields action. The collisions between particle and boundaries can be elastic or inelastic. In past studies, it have been showed in the eccentric pulsating case, without fields and dissipation, one can observe the Fermi Acceleration [1, 2].
Although the system is not conservative, we describe it via Hamiltonian formulation. For our studies, we have considered a constant magnetic field in the perpendicular direction related to the billiard plan, i.e., at the $\widehat{z}$ direction in the cylindrical spheric coordinates $(\widehat{\rho}, \widehat{\theta}, \widehat{z})$; and also a constant electric field in any direction, provided that the particle does not leave the plan. Thus, the Hamiltonian, that is the total energy of the particle for a instant *t*, is given by:

$$H(t) = \frac{1}{2m}\left[p_\rho^2 + \frac{1}{\rho^2}\left(p_\theta - \frac{qB\rho^2}{2c}\right)^2\right] + q\varphi_{(\vec{\mathbf{r}})} \tag{1}$$

where: p_ρ, p_θ are the momenta in $\widehat{\rho}$ and $\widehat{\theta}$ components, respectively. B is the module of magnetic field, q the charge of the particle and $\varphi_{(\vec{\mathbf{r}})}$ is the electric potential.
The Hamilton-Jacobi equations are numerically integrated till the particle finds one of the circles. Due the pulsation, the boundaries transfer momentum to the particle and its kinetic energy is changed, so we do the correction in the total energy at every collision with both external and inner circle using the speed v:

$$E(t) = H(t) = \frac{1}{2}mv^2 + q\varphi \tag{2}$$

We will show that, for a very strong magnetic field, the Fermi acceleration can be suppressed even in the eccentric case with elastic collisions. These results are agreed to the LRA conjecture, because in the static case the trajectories are not chaotic and the particle stays confined in the Whispering Gallery Orbits. However, we found a new way to observe, without dissipation, a phase transition from a crescent energy gain regime to a constant energy level one in that the curvature of the particle's trajectory, due the magnetic field, compensates the external boundary pulsation action in the radial direction.
New studies and statistic analyses are being obtained for searching mechanisms whose limit values of B turn it possible to observe phase transition from constant to crescent energy in the eccentric case.

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Experimental study of firing death in a network of chaotic FitzHugh-Nagumo neurons P15

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The FitzHugh-Nagumo neurons driven by a periodic forcing undergo a period-doubling route to chaos and a transition to mixed mode oscillations. When coupled, their dynamics tend to be synchronized. We show that the chaotically spiking neurons changes their internal dynamics to subthreshold oscillations, the phenomenon referred to as firing death. These dynamical changes are observed below the critical coupling strength at which the transition to full chaotic synchronization occurs. Moreover, we find various dynamical regimes in the subthreshold oscillations, namely, regular, quasi-periodic and chaotic states. We show numerically that these dynamical states may coexist with large amplitude spiking regimes and that this coexistence is characterized by riddled basins of attraction. The reported results are obtained for neurons implemented in the electronic circuits as well as for the model equations. Finally, we comment on the possible scenarios where the coupling induced firing death could play an important role in biological systems.

P16 Phase noise performance of double-loop optoelectronic microwave oscillators

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Optoelectronic oscillators (OEOs) are useful for applications such as radar, time-frequency metrology and lightwave technology, where microwaves with exceptional purity are needed [1]. The purity of microwave signals is achieved thanks to an optical fiber delay-line inserted into the feedback loop providing a quality factor equal to $Q = 2\pi\omega T$, where ω is the microwave frequency and T the delay. Microwaves with frequencies as large as 75 GHz, and a phase noise lower than -160 dBc/Hz at 10 kHz has been achieved [2]. As Q increases with T, a long delay should improve the performance. However strong parasite ring-cavity peaks at the integer multiples of the round-trip frequency limiting the region of low phase noise.

Alternatives consisting in adding the output of two loops with different delay time has been proposed to lower the phase noise or to reduce the level of parasite ring-cavity peaks [3]. Single-loop OEOs suffer from another severe limitation: increasing the gain the system becomes unstable leading to a modulation of the microwave amplitude and thus to a degradation of the spectral purity [4].

Here, we consider a double-loop optoelectronic delay system in which the output of one of the loops is used to modulate the other [2]. Besides reducing the phase noise spurious peaks as linearly coupled dual-loop OEOs, this system allows for stable microwave emission with larger amplitude.

We derive an amplitude equation and determine the parameter region where stable pure microwaves are generated. By including suitable stochastic terms we determine the phase noise performance. By appropriately setting the parameters of the second loop, a significant improvement of performance can be achieved comparatively to the single-loop configuration, as the detrimental effect of the multiplicative phase noise can be reduced up to about 18 dB close to the carrier, while delay-induced spurious peaks can be strongly damped.

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High-speed key exchange using chaotic systems **P17**

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We show here that broadband chaotic systems can be exploited to efficiently exchange ultra-fast keys between two legitimate users, Bob and Alice. Bob is equipped with two chaotic systems, master and slave. The master's output is used to drive Bob's slave and it is also sent to Alice through a public channel. Alice uses this signal to replicate Bob's slave signal. Slave signals are digitalized to construct the private-key. The dynamics [1] can be described by the dimensionless RF voltages of Bob's master (x_1) and slave (x_2) and Alice's slave (y_2),

$$x_1 + \tau_1 \dot{x}_1 + \theta_1^{-1} u_1 = G_1 \cos^2 \left[\Delta(x_1)_{T_1} + \phi_1\right], \tag{1}$$

$$x_2 + \tau_2 \dot{x}_2 + \theta_2^{-1} u_2 = G_2 \cos^2 \left[\Delta(x_1 + x_2)_{T_2} + \phi_2\right] + \sqrt{D_a}\,\xi(t), \tag{2}$$

$$y_2 + \tau_2' \dot{y}_2 + \theta_2'^{-1} v_2 = G_2 \cos^2 \left[\Delta(x_1 + y_2)_{T_2'} + \phi_2' + \sqrt{D_m'}\,\eta'(t)\right] + \sqrt{D_a'}\,\xi'(t), \tag{3}$$

where $\dot{u}_i = x_i$, $\dot{v}_2 = y_2$, $\Delta(z)_{t_0} \equiv z(t - t_0) - z(t - t_0 - \delta t_0)$, θ_i and τ_i are the inverse low and high cut-off frequencies of the amplifier, and G_i is the amplifier gain. We include slave environmental fluctuations as independent Gaussian white noises $\xi(t)$, $\xi'(t)$ with zero mean and correlation $\langle \xi(t)\xi^*(t')\rangle = \langle \xi'(t){\xi'}^*(t')\rangle = \delta(t - t')$. $\eta'(t)$ is a Gaussian white noise modeling signal distortion after fiber propagation and amplification. $\sqrt{D_a}$,$\sqrt{D_a'}$ and $\sqrt{D_m}$ are noise amplitudes. Since x_1 is independent on the slave, the slave parameters cannot be inferred from the transmitted signal. Differential delay plays a major role in confidentiality: If the differential times δT_1 and δT_2 differ by an amount larger than the autocorrelation time, x_1 bears no information on x_2 (cross-correlation and mutual information are negligible) [2]. For Bob and Alice to generate the same private key it is necessary that x_2 and y_2 synchronize. We show that, despite noise, good synchronization can be obtained if the mismatch in the parameters is of the order of a few percent. Synchronization is extremely sensitive to a mismatch in T_2 and δT_2, so that it is considerably degraded already for a relative mismatch of 0.1% and 1%, respectively.

After digitalization of x_2 and y_2, to enhance the uniformity the two most significant bits (MSBs) are discarded. To ensure randomness we have check that the key passes the standard test NIST SP 800-22 test even when is generated from free-noise system. The third MSB is used to construct the key and the others are discarded to avoid noise sensitivity. We show that while the authorized receiver can successfully generate the key an unmatched receiver will generate a key with a large number of errors. Particularly relevant are T_2 and δT_2, which can be accurately matched in real systems, and which contribute significantly to confidentiality: 0.0003% mismatch in T_2 leads to 20% mismatched bits in the key.

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P18 Synchronization and Quantum Correlations in Harmonic Networks

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Synchronization phenomena have been observed in a broad range of physical, chemical and biological systems but there are few attempts to describe them in the quantum regime. Most of the attention in this regime has been devoted to the problem of entrainment induced by an external driving [1] and not to spontaneous synchronization. We also mention recent research by different groups on synchronization of nano/microscopic systems [2]. Even if these works [2] are concerned with classical (average) properties, such optomechanical devices are indeed susceptible of having quantum behaviour, being the subject of an intense experimental effort. In [3], for the first time, we established the connections between the phenomenon of synchronization and quantum correlations.
We initially considered a fundamental quantum system [3, 4], two coupled and detuned quantum harmonic oscillators dissipating into the environment. Different dissipation mechanisms, corresponding to the situations in which (i) every oscillator dissipate in an independent bath (separate baths, SB), or (ii) the correlations length in the bath is larger than the oscillators systems (common bath, CB), are considered. Analyzing the dynamics of the system [4] for Gaussian states, we identify the conditions leading to spontaneous synchronization. The mechanism of synchronization in this linear system is novel and the ability of the system to oscillate at a common frequency is related to the existence of disparate decay rates of the normal modes [3]. We then analyzed different measures of correlations and their temporal decay due to decoherence. We showed that this phenomenon is accompanied by robust quantum discord [5] and mutual information between the oscillators, preventing the leak of information from the system.
Once identified the conditions for synchronization and its quantum aspects, we have extended our analysis to the case of a quantum network [6]. At difference from the case of a couple of oscillators, we showed that even in presence of diversity between the nodes (in their frequencies and in the couplings with the rest of the network) it is possible to have asymptotic synchronization and entanglement. The increased number of nodes allows to discuss several situations, like the possibility to synchronize the whole network by tuning one of the oscillators frequencies, or by inducing synchronization only in one part of the cluster, or the conditions to connect two oscillators to a network inducing asymptotic entanglement between them.

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Adler synchronization of spatial laser solitons pinned by defects **P19**

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Laser cavity solitons (LCS) are transverse, nonlinear, self-localized and dissipative states that possess both translational and phase invariance. LCS interaction and synchronization properties in broad-area semiconductor lasers have the potential for massive parallelism and the formation of complex arrays. Phase-locked bound states with solitons have been predicted in mode-locked lasers for the temporal case [1] and in lasers with saturable absorbers for the spatial case [2]. Corresponding phase-quadrature states have been observed in fiber lasers [1].
Here we present a different kind of soliton locking. We demonstrate experimentally and theoretically Adler-type locking and synchronization of spatial LCS in a vertical-cavity surface-emitting laser (VCSEL) with an external Bragg grating that provides frequency-selective feedback [3]. In particular we explain the role played by defects resulting from fluctuations during the epitaxial growth process.
The experiment was performed with a VCSEL and a volume Bragg grating (VBG) in a self-imaging configuration[4]. A piezo-electric transducer was used to minutely tilt the VBG with respect to the optical axis leading to a differential change in the feedback phase and allowing the tuning of $\Delta\omega$. When performing such a scan, a region of frequency and phase locking appears, identified by a high fringe visibility in the far field.
The dynamics of LCS in a semiconductor laser with feedback is well captured by a generic cubic complex Ginzburg-Landau equation coupled to a linear filter [4]. Without inhomogeneities there are exact solutions corresponding to stable single-frequency chirped-sech solitons with two free parameters: location and phase. The interaction of two solitons makes them spiral slowly to fixed relative distances and phase differences around $\Phi = \pi/2$ unless merging takes place. $\Phi = 0, \pi$ are also possible but correspond to saddles that are either phase or distance unstable.
Small inhomogeneities lead to pinning and small changes in the LCS frequency. If defects are located close enough, solitons interaction locks their frequencies to a common value. The phase difference Φ relaxes to stationary values that depend on the detuning generated by inhomogeneities $\Delta\omega = \omega_2 - \omega_1$. We show that in the locking region both the numerical and experimental results are well described by the Adler model for synchronization between two coupled oscillators with different bare frequencies,

$$\dot{\Phi} = \Delta\omega - \varepsilon \sin(\Phi)\,. \tag{1}$$

The fringe phase varies smoothly and quasi-linearly with the detuning of the external cavity. The width of the locking range is close to the expected value of π and the transitions to and from frequency and phase-locking are rather abrupt.

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P20 Tuning the period of square-wave oscillations in two delay coupled systems with delay feedback

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Time delays in physical, biological or chemical systems are a source of instabilities and complex dynamics [1]. In optical and optoelectronic systems with feedback, for instance, typically the time scale associated to the feedback is slower than the intrinsic time scales of the system and thus delay terms arise in a natural way. The study of the time-delayed dynamics in laser and optoelectronic systems has been motivated by applications such as the stabilisation of the output in control systems or the generation of controllable periodic or chaotic signals. Another instance in which delay naturally appears is when considering coupled systems where delay is due to the finite propagation time from one system to another.

An interesting example of dynamical regime that can arise through time-delayed feedback is square-wave switching. The generation of tunable pulsating dynamics has been studied during the past few years [2], motivated by fundamental interest and also towards applications such as optical clocks and other binary logical applications, generation of stable microwave signals or optical sensing.

In this work we focus on the dynamics of two delay systems mutually coupled with delay. As a prototypical delay system we consider two mutually coupled optoelectronic oscillators. Systems of optoelectronic oscillators exhibit a rich variety of dynamical regimes [3] with different potential applications. They have been used as chaos generators for secure chaos-based communications [4]. These devices have also been proposed and studied to produce efficient ultra-pure microwaves in the periodic regime [5].

We show that interplay between self- and cross- delay times has a critical role on the synchronization of the two oscillators. In particular we will study the conditions on which square-wave periodic solutions in both systems appear. Synchronized in-phase solutions arise only when the ratio between the delays is between two odd numbers while synchronized out-of-phase solutions appear for ratios given by an odd and an even number. Furthermore, we will show the coexistence of multiple periodic synchronized solutions for fixed parameter values. In this circumstances the system can be set to generate square-wave oscillations with different periods just changing the initial condition.

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Longitudinal and large scale characterization of freely self-organized cultured neural networks P21

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The study of how an assembly of isolated neurons self-organizes to form a complex neural network is a fundamental problem to be addressed [1]. Previous studies highlighted that the organization of the neuronal network before reaching its mature state is not random, being instead characterized by a high clustering and short paths [2]. In vitro primary cultures of dissociated invertebrate neurons from locust ganglia are used to investigate the morphological evolution of assemblies of living neurons, as they self-organize from collections of separated cells into elaborated, modular, networks. In particular, we developed a complete software for the identification of neurons and neurites location, able to ultimately extract an adjacency matrix from each image of the culture. This, on its turn, allowed us to perform statistical analyses of some relevant network topological observables at different stages of the culture's development, and to quantify the main characteristics of a generic assembly of isolated neurons when it self-organizes to form a complex neural network. Time evolution of associated micro- and meso-scales of the graph is reported, which allows to draw first conclusions on the main mechanisms involved in the large-scale evolution of the network' connectiveness.

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P22 Towards a biophysical description of contractile pulses of amnioserosa cells during dorsal closure

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During late Drosophila embryogenesis, an epidermal opening on the dorsal side of the embryo is sealed by the constriction of an extra-embryonic tissue, the amnioserosa. During the initial phase of this morphogenetic process, called dorsal closure, the cells of the amnioserosa exhibit pulsed contractions correlating with oscillatory changes of each individual apical cell surface. Shape oscillations have periods on the order of a few minutes. They are driven by the active dynamics of the actomyosin cortex, a protein meshwork underlying the apical cell membrane of the amnioserosa cells and mainly consisting of crosslinked actin filaments and myosin motor proteins. An understanding of the biophysical mechanism at the heart of the observed dynamic instability is still missing. Here, we present preliminary results based on quantitative image analysis of wild type and mutant embryos, laser cutting experiments, as well as theoretical considerations in a dynamical systems framework. Our work suggests that the observed dynamics can be accounted for by an effective nonlinear elasticity of the apical cell surface, accumulation of cortical material due to local shape change and the constant remodelling of the cortex with a turn-over time of about one minute.

P23 Multivariate extensions of recurrence networks: Geometric signatures of coupled nonlinear systems

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Complex network approaches to time series analysis have recently proven their great potential for characterizing important properties of individual stochastic processes or dynamical systems. However, in the real-world such systems typically do not evolve completely isolated from each other, but exhibit mutual interactions with their neighborhood. Following this idea, we propose here extending the recent graph-theoretical view on individual systems towards a coupled network approach to interacting systems. Specifically, we illustrate how to extend the particularly successful concept of recurrence networks to studying dynamical interrelationships between two or more coupled nonlinear dynamical systems exclusively based on their attractors' geometric structures in phase space.

Predator-prey systems with seasonal migration P24

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Population models where two or more species exhibit predator-prey relationships have long been of interest to researchers working on both dynamical systems and ecological modelling [1]. Most of these models have been static where the different species have been constrained to a specific area. However, even though seasonal migration is a common occurrence in nature [2, 3], surprisingly few attempts have been made to model predator-prey systems that incorporate such behaviour. The possibility for predator-prey problems that allow for one or more of the species to undergo mass migration open up a range of new possibilities from a dynamical point of view. Furthermore, systems of this type can be modeled in a variety of different ways. Here we focus on two different approaches, namely, ordinary and partial differential equations, where the former can be seen as a compartment model and the latter a spatial model. In both cases the inclusion of the seasonal periodicity is key in understanding their behaviour. The dynamics arising from the different migration models will be compared, with particular emphasis placed on the stability of periodic solutions and bifurcations.

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Scaling exponents of rough surfaces generated by damage spreading in the Ising model P25

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We carry out a study of the phase transitions in the damage spreading (DS) in the one-dimensional Ising model under a dynamic introduced by Hinrichsen and Domany (HD) [1] and mapping of the spin configurations to a solid-on-solid growth model, resulting in an aggregate which is compact (no vacancies) and without surface overhangs [2]. A system is said to exhibit DS [3] if the "distance" between two of its replicas, that evolve under the same thermal noise but from slightly different initial conditions, increases with time. The dynamic introduced by HD exhibit nondirected percolation universality class continuous phase transitions to absorbing states, exhibit parity conservation (PC) law of kinks. The kinks (00's and 11's) of these models exhibit mod 2 parity conservation and the absorbing state is doubly degenerated. They are characterized by different exponents which are related to the PC universality class [4]. We have obtained such exponents through Monte Carlo simulations, variating the lattice size at critical probability. We estimated the growth exponent β_w at short times, such as, other critical exponents associated to the surface growth (α and z). Our results are in good agreement with those expected for PC universality class. The critical roughening exponents, expected to belong to the PC universality class, were measured using power law relations valid at criticality. Supported by Capes, CNPq and Fapemig

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P26 Implementation of an optoelectronics logic gate dynamically flexible using a laser fiber, numerical study

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We present the implementation of a system to reproduce the behavior of a dynamic logic gate. The dynamic logic gate consists of three elements: a fiber laser in chaotic regimen, a threshold controller and the output of the logic gate. The output signal of the fiber laser is sent to the logic gate input as to the threshold controller; threshold controller output signal is sent at the entrance of the logic gate and also fed back to the fiber laser, which changes their dynamic behavior. The output of the logic gate consists of a difference amplifier; this compares the signals sent by the threshold controller and the fiber laser, resulting logic output that depend on an accessible parameter in threshold controller. We present the experimental and numerical results of the implementation of a dynamic logic gate using fiber laser, which demonstrates the ability to change the type of logic gate by modifying a parameter of threshold control.

P27 Formation of two-kink solitons due to the presence of a localized external force

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Recently, it has been reported the existence of stable dissipative solitons supported by the presence of a localized gain in optical systems [1, 2]. A further investigation has studied the existence of multipole solitons maintained by a localized parametric gain in focusing and defocusing media[3]. In the present work, we address the formation of two-kink and multi-kink solitons in the sine-Gordon model under the perturbation of a localized space-dependent force. The existence of two-kink soliton solutions in polynomial potentials was first reported by D. Bazeia *et al.* in a special type of scalar field systems [4]. In contrast, we show that a pair of two-kink solitons can be formed in the sine-gordon model during the process of kink breakup by internal mode instabilities [5]. The formation process of these bounded states is an interplay between the solitonic repelling interaction and the localized external force, resulting in a separation or a packing of several kinks. Multikinks states can be also observed for larger values of the external force. Based on energy considerations, we are able to predict and control the formation of multistates by varying the external force parameters. A possible experimental realization using Josephson junctions is proposed.

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Dynamics of the early stage of pattern formation in the ferrocyanide-iodate-sulfite reaction-diffusion system: branching and budding P28

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We have studied the early stage of pattern formation in the ferrocyanide-iodate-sulfite reaction using a home-made one-side fed unstirred spatial gel reactor (OSFR) that was connected to a continuous flow stirred-tank reactor (CSTR). Following Turing's theory for pattern formation in reaction-diffusion systems, the gel has been prepared to contain polyacrylic (PA) in order to slow down the diffusion of the activator species, the hydrogen ion. The relationship between the PA concentration (varied between 0-12 mM) and the wavelength of the labyrinth type patterns has been examined while no other parameter has been changed. The formation and development of the patterns had been recorded by a digital camera, and the movies were analyzed by a computer program. Peculiar branching and budding mechanisms have been found to be responsible for the dynamics of the early stage of the pattern formation. The complexity of the labyrinth (number of branches) greatly depends on the PA concentration.

Building a triple agent model for financial markets P29

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Agent-based models have become common in financial research. An agent-based model is a way of describing a complex system by looking at the individual parts and modelling their interactions. Then the model is allowed to run and often produces results which could not be predicted by examining the individual parts alone. This phenomenon is called *emergent behaviour*.
The motivation behind the model which will be presented is to understand the reasons for the non-Gaussian distribution of returns and the volatility clusters in financial data. These are two of the many stylised facts which are common to financial data collected from many diverse sources [1]. The model aims to find the simplest trading strategies necessary to produce leptokurtic returns with volatility clustering. We find three ingredients essential to this outcome; traders with some memory, technical traders that trade in line with trends in the price, and fundamental traders who know the "fundamental value" of the stock and trade accordingly. With these three basic types of agents the relevant characteristics emerge in the produced time series. The model is further analysed in order to obtain an analytic description of the agents and their trading strategies.

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P30 Phase diagram of a cyclic predator-prey model with neutral-pairs exchange

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In the present work we obtain the complete phase diagram of a four species predator-prey lattice model by using the recently proposed Gradient Method. We consider cyclic transitions between consecutive states, representing invasion or predation, and allowed the exchange between neighboring neutral pairs. By applying a gradient in the invasion rate parameter one can see, in the same simulation, the presence of two symmetric absorbing phases, composed by neutral pairs, and an active phase that includes all four species. In this sense, the study of a Single-Valued Interface and its fluctuations give the critical point of the irreversible phase transition and the corresponding universality classes. Also, the consideration of a Multivalued Interface and its fluctuations bring the percolation threshold. We show that the model presents two lines of irreversible first-order phase transition between the two absorbing phases and the active phase. Depending on the system parameters, these lines can converge into a triple point that is the beginning of a first-order irreversible line between the two absorbing phases, or end in two critical points that belong to the directed percolation universality class. Standard simulations confirm the order of the transitions as determined by the Gradient Method. Besides, we show that the percolation transition lies on the active phase, and when it disappears, the model presents a first-order percolation transition, as already found in other similar models.

P31 Interfacial properties in a discrete model for tumor growth

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We propose and study by means of Monte Carlo numerical simulations a minimal discrete model for avascular tumor growth, which can also be applied for the description of cell cultures *in vitro*. The interface of the tumor is self-affine and its width can be characterized by the following exponents: (i) the growth exponent $\beta = 0.32(2)$ that governs the early time regime, (ii) the roughness exponent $\alpha = 0.49(2)$ related to the fluctuations in the stationary regime, and (iii) the dynamic exponent $z = \alpha/\beta \simeq 1.49(2)$, which measures the propagation of correlations in the direction parallel to the interface, i.e. $\xi \propto t^{1/z}$, where ξ is the parallel correlation length. So, the interface belongs to the KPZ universality class in agreement with recent experiments of cell cultures in vitro. Furthermore, density profiles of the growing cells are rationalized in terms of traveling waves that are solutions of the Fisher-Kolmogorov equation. In this way, we achieved excellent agreement between the simulation results of the discrete model and the continuous description of the growth front of the culture/tumor.

A quantitative model for tissue homeostasis **P32**

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Homeostasis is the regulation of the internal environment of a system in order to maintain some property in a stable, relatively constant condition. In tissue homeostasis, the relative number of cells should be maintained, therefore stem cells must balance self-renewal with differentiation, in a dynamic equilibrium. Understanding how this process is controlled in adult tissues represents a defining question in stem cell biology.
The Drosophila midgut, which is analogous to the mammalian stomach, small intestine, and colon, has been identified as a powerful system in which to study mechanisms that control homeostasis. Early works have established a model of tissue turnover based on the asymmetric division of intestinal stem cells. In that way, one stem cell daughter always remains pluripotent and other differentiates. Recently, an alternative scenario is proposed from the quantitative analysis of clonal fate data [1]. It has been shown that Drosophila midgut tissue turnover involves symmetrically dividing stem cells, whose cell fate should be defined after the division. This mechanism can lead to stem-cell loss since both daughters can differentiate.
What is the molecular mechanism for the symmetry breaking in stem cell daughter cells? What is the role of the lateral inhibition in this system? What is the relevant genetic pathway in order to maintain the homeostasis? How do the spatial and temporal heterogeneities of cell distribution affect fate decision?
We propose a multiscale reaction-diffusion model to address these questions. Different cell types (steam cells, committed cells and differentiated cells) and molecules (cytokines, Notch, Delta, Jak-Stat) are considered. A sparse hexagonal lattice mimics the spatial distribution of cells and allows variability and fluctuations at cell proportion. Comparisons with experimental data on clone analysis are presented.

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P33 Chimera states in networks of excitable elements

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Chimera states are a peculiar dynamical phenomenon observed in systems of nonlocally coupled elements which split into two domains: one coherent and phase locked and another incoherent and desynchronized[1]. Only recently, chimera states were experimentally realized in populations of coupled chemical oscillators as well as optical coupled-map lattices[2]. Chimera states could also be of importance in certain biological systems: many birds as well as dolphins sleep with one eye open, in the sense that one hemisphere of the brain is synchronous while the other is asynchronous (unihemispheric sleep)[3]. The study of chimera states in the context of neural applications is, therefore, of great interest. Recently it was shown that multi-chimera states exist in rings of nonlocally coupled FitzHugh-Nagumo oscillators[4], a paradigmatic model in neuroscience. In this work, we consider networks of Hindmarsh-Rose oscillators [5] which are the prototype system for type-I neuron excitability[6]. Various interesting synchronization patterns including chimera states are observed. The effect of the coupling strength and the network topology on the existence and stability of the chimera states is investigated both in a single network and in a system of two coupled neuron populations.

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CANCELLED. ~~The nature of weak generalized synchronization in chaotically driven maps~~ P34

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Weak generalized synchrony (WGS) in a drive–response system occurs when the response dynamics is a unique but nondifferentiable function of the drive, in a manner that is similar to the formation of strange nonchaotic attractors in quasiperiodically driven dynamical systems. We consider a chaotically driven monotone map and examine the geometry of the limit set formed in the regime of weak generalized synchronization. The fractal dimension of the set of zeros is studied both analytically and numerically. We further examine the stable and unstable sets formed and measure the regularity of the coupling function. The stability index as well as the dimension spectrum of the equilibrium measure can be computed analytically.

Preferential growth of weighted mutualistic networks P35

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Mutually beneficial interactions between two agent classes, such as plant-pollinator or plant-seed disperser, are best represented by weighted mutualistic bipartite networks [1]. Those networks have been repeatedly reported to show a nested structure. While several metrics for measuring nestedness in weighted mutualistic networks have been proposed in the past few years [2], most dynamic models in the literature aim to reproduce just the binary nested structure ignoring the development of the weighted pattern [3, 4]. We introduce a simple dynamic model based on a modified preferential attachment rule for bipartite networks. Our model simulates the growth of a mutualistic network generating weighted interaction matrices that we compare with empirical data from several real biological networks [5]. The resulting network shows a power-law degree distribution in both cases: plants and animals. Furthermore, the model reproduces accurately the nestedness behavior.

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P36 Synchronization and spatial coherence of neuronal populations increase the probability of seizure termination.

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Traditionally seizures are described as an extreme and pathological form of synchronization of large neuronal populations. Recent observations suggest that synchronization during seizures is much more complex and surprisingly extreme synchronization may contribute to seizure termination. In this study we examined in detail temporal profile of synchronization and spatial dynamics of neuronal populations during the course of seizures. Experiments were performed in vitro in rat hippocampal slices perfused with artificial cerebrospinal fluid containing low calcium (0.2 mM). Field potentials from the hippocampal CA1 region were recorded using multiple extracellular electrodes. Results demonstrated that seizures were characterized by initial low levels of synchronization which gradually increased during their course. Phase coherence (order parameter) between individual recording sites progressively increased and it reached its maximal value towards the end of the seizure. Increase in phase coherence was accompanied by progressive slowing down of instantaneous frequency of seizure activity and decreased variance of instantaneous frequency between recording sites of seizure generating region. Final stages of seizures were characterized by spatially coherent activity with common frequency, stable site of initiation of ictal discharges and highly regular pattern of their propagation across CA1 region. Seizure termination itself was characterized as a simultaneous disappearance of ictal discharge over entire CA1 region ('seizure death'). This study demonstrates complex evolution of synchronization between neuronal populations during the course of seizures. Our observations suggest that early parts are generated by multiple and weakly coupled neuronal populations generating seizure activity at various frequencies. Progressive increase in coupling results in formation large cluster of strongly coupled neuronal populations generating ictal activity at identical frequency. Such arrangement may provide spatiotemporal substrate for seizure termination and resembles oscillator death phenomenon observed in systems with strongly coupled oscillators. Supported by Karel Janecek Endowment in Support of Science and Research (2012/10) grant and Czech Ministry of Health grants (IGA NT11460-4/2010, IGA NT 14489-3/2013).

P37 Emergence of epidemics in rapidly varying networks

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We describe a simple model mimicking disease spreading on a network with dynamically varying connections, and investigate the dynamical consequences of switching links in the network. Our central observation is that the disease cycles get more synchronized, indicating the onset of epidemics, as the underlying network changes more rapidly. Further, the influence of changing links is more pronounced in networks where the nodes have lower degree, and the disease cycle has a longer infective stage. Lastly, we also observe finer dynamical features, such as beating patterns in the emergent oscillations and resonant enhancement of synchronization, arising from the interplay between the time-scales of the connectivity changes and that of the epidemic outbreaks.

Pattern formation and control in networks of bistable elements P38

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Traveling fronts and stationary localized patterns in bistable reaction-diffusion systems have been broadly studied for classical continuous media and regular lattices. Analogs of such non-equilibrium patterns are also possible in networks. Here, we consider traveling and stationary patterns in bistable one-component systems on random Erdös-Rényi, scale-free and hierarchical tree networks. As revealed through numerical simulations, traveling fronts exist in network-organized systems. They represent waves of transition from one stable state into another, spreading over the entire network. The fronts can furthermore be pinned, thus forming stationary structures. While pinning of fronts has previously been considered for chains of diffusively coupled bistable elements, the network architecture brings about significant differences. An important role is played by the degree (the number of connections) of a node. For regular trees with a fixed branching factor, the pinning conditions are analytically determined. Furthermore, effects of feedbacks on pattern formation phenomena are investigated. Localized stationary activation patterns, which resemble stationary spots in continuous media, have been observed in the networks. The active nodes in such a pattern form a subnetwork, whose size and structure can be controlled by the feedback intensity.

Chimera states for repulsively coupled oscillators P39

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We discuss the appearance of the chimera states for a network of repulsively coupled N phase oscillators of the Kuramoto-Sakaguchi type

$$\dot{\varphi}_i = \omega + \frac{1}{2P}\sum_{j=-P}^{P}\sin(\varphi_{i+j} - \varphi_i - \alpha), i = 1, ..., N. \quad (1)$$

Each oscillator φ_i of the network is coupled with equal strength to its P nearest neighbors on either side, index i is periodic mod N, phase shift $\alpha \in (\pi/2, \pi]$. In the case coupling in the network is repulsive, i.e. it works against synchronization. In the parameter plane (α, r), where $r = P/N$, we uncover a cascade of the chimera states with increasing number of the regions of irregularity(illustrated for $N = 100, 200, 1000$). Each chimera is characterized by the even number of narrow layers of incoherence, "heads", where the average frequencies $\bar{\omega}_i$ are different from the frequency of the main cluster. The neighboring regions are slightly intersecting which means that respective chimera types can coexist. We report three scenarios for the chimera birth in the N-dimensional network phase state: 1) via saddle-node bifurcation on a resonant invariant circle, also known as SNIC or SNIPER, 2) via blue-sky catastrophe, when two periodic orbits, stable and saddle, approach each other creating a saddle-node periodic orbit, and 3) via homoclinic transition, when the unstable manifold may come back crossing the stable manifold of the saddle-node. For $N = 1000$ and $P = 130$, we estimate dynamical complexity of the chimera behavior by calculation of Lyapunov exponents and Laypunov dimension. The complexity grows with decreasing α, and Lyapunov dimension is slightly smaller than the total number of the incoherent oscillators K^h in the chimera heads. We also demonstrate chaotic wandering of the chimera states for different value of the parameter of α. Finally, we obtain two-dimensional chimera states for an analog of the network (1) at 2-D torus. Our simulations approve that main properties of the repulsive chimera states survive also in the two-dimensional case.

P40 Consistency, complex networks and mild cognitive impairment

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Mild Cognitive Impairment (MCI) has been described as an intermediary state between healthy aging and demential [1]. Approximately ten percent of population with MCI ends up with Alzheimer's per year. For this reason, several approaches from different fields of knowledge have focused in understanding the nature of this pathology [2]. In this study, we show preliminary results from complex network theory adapted to Magnetoencephalograpy (MEG) data, obtained from two groups of fourteen subjects each: Controls and MCI Patients (C, P) respectively, in order to make inferences about neurological basis related to this medical condition.
MEG data were recorded from 147 nodes located on individual scalps, and the Synchronization Likelihood algorithm was used for each node, obtaining the so-called self-consistency (SC) value from MEG time series. Self-consistency measures the ability of each recorded cortical region to behave in the same way when a given input signal is repeated.
A new methodology for features differentiation [3], based on comparing linearly all possible permutations of SC patient and control features, is used in order to define a limit value, -named Z-Score-, that separate the SC standard deviations from control and MCI groups. Large values of SC standard deviations are represented as edges in the networks created under this methodology. These anomalous networks are weighted and non directed, and they unveil important topological differences between both groups.
This procedure evidences the existence of two network classes: heterogeneous and star-like shapes, associated to the control and MCI group respectively. These networks were analyzed using different metrics [4] Strength, Degree, Clustering, Mean Path, Local and Global Efficiency, indicating those cortical regions related to the main differences between groups induced by the disease.

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Decision support systems towards the intelligent analysis and classification of cerebral inflammation as measured with multi-parametric Magnetic Resonance P41

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Cerebral inflammatory responses underlie the most morbid and prevalent neurological disorders, including cancer, ischemia, neurotrauma or neurodegeneration. In most cases, current bioimaging methods are not able to discriminate unambiguously between the primary pathology and the associated inflammatory response. To this end, we report here a novel intelligent decision support system to discriminate between inflamed and healthy mouse brain using multi-parametric Magnetic Resonance Imaging. Linear Discriminant Analysis was applied to the segmented pixels of the hippocampus. An initial component vector of features for each pixel describing the intensity values of the acquired datasets was used. Feature inclusion was applied sequentially considering the highest R^2 value of each feature after performing a regression analysis to the model constructed. Features were included until the adjusted Root Mean Square Error (RMSE) value decreases ($< \epsilon$). At this point, the remaining features considered are the ones which contribute to the best cost-effective model of classification. In these terms, this novel approach assesses the best combination of MRI features to discriminate inflammation from healthy tissue, improving the clinical workflow and diagnosis in cerebral inflammation pathologies.

Dynamics of the individual properties and the collective behavior in living matter P42

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Collective behavior of living matter are composed of characteristic individuals. The individuality is very important because it deeply relates to the collective behavior. Therefore we studied the dynamics of the collective behavior by changing the individual properties. We represent an i-th individual motion as dynamical equations of a self-propelled particle in two dimensions :

$$\dot{\mathbf{v}}_i(t) = (1 - |\mathbf{v}_i(t)|^{\alpha})\,\mathbf{v}_i(t) + \mathbf{F}^{env} + \mathbf{F}^{s}(t) \quad (1)$$
$$\dot{\mathbf{x}}_i(t) = \mathbf{v}_i(t) \quad (2)$$

where the first term on the right side of the equation (1) acts to keep constant speed, the α represents the strength to be constant speed, the $\mathbf{F}^{env}$ is the environment force and $\mathbf{F}^{s}(t)$ is the interaction between the individuals in the swarm. We apply several types of interaction forces to $\mathbf{F}^{s}(t)$ like globally coupled inter-molecular force or the Vicsek model-like short range interaction [1]. We assume the individual properties as the α and the interaction force type in the equations. To study the dynamics of collective behavior, we adopt Lyapunov exponents used in characterizing their chaotic behaviors for the dynamical system [2]. We characterize effects of the individual properties on the stability of the collective behavior by using the Lyapunov exponents. We simulate this dynamical model with N individuals with the different individual parameters and show the numerical results of the effects of the parameters on the collective behavior.

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P43 Extreme intensity pulses in a semiconductor laser with a short external cavity

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We present a numerical study of the pulses displayed by a semiconductor laser with optical feedback in the short cavity regime, such that the external cavity round trip time is smaller than the laser relaxation oscillation period. For certain parameters there are occasional pulses, which are high enough to be considered extreme events. We characterize the bifurcation scenario that gives rise to such extreme pulses and study the influence of noise. We demonstrate intermittency when the extreme pulses appear and hysteresis when the attractor that sustains these pulses is destroyed. We also show that this scenario is robust under the inclusion of noise.

P44 The role of diffusion and shear diversity in collective synchronization

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Reaction-diffusion systems consisting of a large number of degrees of freedom display dynamical regimes that successfully describe a number of spatio-temporal patterns found in nature. In particular, systems composed of many interacting aggregates of heterogeneous, self-oscillating elements, often show oscillations at the macroscopic level as a consequence of the collective synchronization of the individual oscillators. This important phenomenon is observed in systems ranging from biology to chemistry, physics and engineering. An appropriate model to study collective synchronization is the mean-field version of the complex Ginzburg-Landau equation (CGLE) with heterogeneity. Here we investigate the synchronization dynamics of a model obtained from the phase reduction of the mean-field CGLE with heterogeneity. The analysis is carried out using the recently proposed "Ott-Antonen anzatz", which in our case permits to drastically reduce the large dimensionality of the original system to a set of two first order, nonlinear differential equations. The well known Kuramoto model predicts that, if oscillators have independently distributed natural frequencies and common shear (or nonisochronicity), the transition from incoherence to collective synchronization occurs at large enough values of the coupling strength. In contrast, here we demonstrate that shear diversity cannot be counterbalanced by a general diffusive coupling leading to synchronization. Indeed, we present the first exact results of a generalization of the Kuramoto model that illustrate the role of dissipative and reactive couplings on the synchronization transition, and show that the onset of collective synchrony is impossible if the width of the shear distribution exceeds a precise threshold. Interestingly, this general result holds true as far as coupling is not purely reactive. In this case, the synchronization threshold turns out to depend on the mean of the shear distribution, but not on all the other distribution moments.

Infinite modal map and on-off intermittency P45

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On-off intermittency which is one of the weak chaos is a phenomenon randomly repeating laminar behavior and instantaneous burst. It was found by Fujisaka and Yamada (1985), using a coupled chaos system, and observed from many numerical and experimental systems later. On-off intermittency is said to have some universally statistical laws: the distribution of laminar phases is an asymptotic power law with exponent -3/2, and the distribution of the state variable is an inverse power law in neighborhood of the onset of intermittency. Usually, it is modeled by a multiplicative stochastic process. However that deterministic mechanism is not known actually. In this situation, we found a purely deterministic model which is expressed by a multiplicative stochastic process different from an usual. Our model is generated by an infinite modal map in one dimension, which is extracted near the homoclinic loop of a saddle-focus by L. P. Shilnikov. In our model also, their universally statistical laws were observed. But, different ones were found in the case of changing the parameters. We report the transitions from the universal laws, and show a theoretical result of our multiplicative stochastic process.

P46 Complex network analysis of connectivity patterns from MEG data of epileptic patients

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The aim of this study is to analyze the complex network parameters obtained from the connectivity patters detected in magnetoencephalography (MEG) recordings during resting state of two different types of epileptic patients compared to healthy subjects. Thirty participants were studied: 10 patients suffering from frontal focal epilepsy (FE), 10 patients suffering from generalized epilepsy (GE) and 10 healthy subjects (HS). For the characterization of epileptic syndromes the seizure classification and other criteria, e.g. case history, age of first manifestation, neurological findings, EEG and MRI were used. MEG recordings were completed with the 306-channel Elekta Neuromag® system (102 magnetometers and 204 planar gradiometers). To correct the head position and the associated movement-related artifacts, a spatio-temporal signal space separation method (tSSS) with movement compensation was realized. MEG data was acquired at a sampling rate of 1 kHz. A period of 10 min of resting state with closed eyes was selected for the study. All the analysis was performed over 1200 non-overlapping segments (the 40 most stationary segments per subject, using the KPSS test for stationarity) of 5000 ms, far from recent epileptic discharges. A downsampling to 500Hz was applied. The Phase Synchronization (PS) analysis was performed using the Phase Locking Value, Phase Lag Index and Phase Slope Index. Testing with surrogate data the significance of the computed synchronization index value for each pair of sensors. Thus, obtaining the connectivity matrix for each single subject. To characterize the network structure of brain activity, we evaluated a list of measures for weighted graphs. In this approach, MEG sensors were considered as vertices and the PS values between sensors as edge weights. The edge weight represents the strength of the connection between the vertices. We focused on two global parameters: the average degree and the strength and two measures of segregation: the clustering coefficient and the modularity. To statistically compare network parameters from the three groups (FE, GE, HS), we performed a Kruskal Wallis test, and in those cases where this test was significant, we further analyzed pairwise difference between any two groups by means of a two-sided rank sum test, obtaining significant differences among the three groups.

Analytical properties of autonomous systems controlled by extended time-delay feedback in the presence of a small time delay mismatch P47

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The application of the delayed feedback control (DFC) or extended DFC (EDFC) algorithms to dynamical systems requires the knowledge of the period of unstable periodic orbit (UPO). For autonomous systems, this period is a priori unknown. An analytical treatment of this problem was first attained by W. Just et. al. [1]. The authors derived an analytical expression for the period of stabilized orbit depending on the delay time in the case of a small delay mismatch. Starting from the autonomous system subject to the DFC $\dot{\mathbf{x}}(t) = \mathbf{F}\left(\mathbf{x}(t), K\left\{g[\mathbf{x}(t)] - g[\mathbf{x}(t-\tau)]\right\}\right)$ (here $\mathbf{x}$ denotes the phase space variables, $g[\mathbf{x}]$ is the measured scalar quantity, τ is the delay time, and K is the control amplitude) they obtained an expression for the period Θ of the periodic solution of the controlled system as an expansion with respect to the small mismatch $\tau - T$ (here T is the period of unstable periodic orbit of the free system):

$$\Theta(K,\tau) = T + \frac{K}{K-\kappa}(\tau - T) + \mathcal{O}((\tau - T)^2), \tag{1}$$

where κ denotes a system parameter which captures all of the details concerning the coupling of the control force to the system. In this work, we present more general result than presented in [1]. Our approach is based on the phase reduction method adapted to the system with time delay [2]. We start from the autonomous system controlled by the EDFC:

$$\dot{\mathbf{x}}(t) = \mathbf{F}\left(\mathbf{x}(t), K\left\{(1-R)\sum_{n=1}^{\infty} R^{n-1} g[\mathbf{x}(t-n\tau)] - g[\mathbf{x}(t)]\right\}\right) \tag{2}$$

The main idea of our approach is based on the splitting of the control force in non-mismatched and mismatched components [3]. The non-mismatched component stabilizes the UPO while the mismatched component induces a small perturbation that can be treated by the phase reduction theory adapted to time-delay systems. As a result we derive a more general expression for the period of the controlled system:

$$\Theta(K,\tau) = T + \frac{K}{K-\kappa(1-R)}(\tau - T) + \mathcal{O}((\tau - T)^2). \tag{3}$$

Another advantage of our approach is that we show how the parameter κ depends on the measured scalar quantity $g[\mathbf{x}]$. The results are important for the practical implementation of the EDFC algorithm, since they facilitate the determination of the unknown period in experiments.

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P48 Front pinning induced by spatial inhomogeneous forcing in a Fabry-Pérot Kerr cavity with negative diffraction

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In a bistable system, the front dynamics connecting two states is a problem concerning many domains of physics [1, 2]. In this system, under a parameter breaking symmetry, the front propagates, except at the Maxwell point. To observe front locking behavior, a spatial periodic forcing has been proposed [3]. In optics, usually we work with Gaussian laser beam which presents inhomogeneous spatial profile, so a natural question arises: Is the dynamics of fronts in optical system affected by an inhomogeneous spatial profile? In the present work, we study front pinning phenomena due to a Gaussian optical forcing. The final pattern is a localized state bounded by two pinned fronts.
We develop an analytical model of front dynamics subjected to spatial forcing from the imperfect pitchfork equation [4]. Under a parabolic forcing approximation, we obtain an analytical expression of the front core trajectory. The analytical study is verified by numerical simulations of this model with parabolic and Gaussian forcing. In this latter case, the numerical simulations show a transitory regime where the front propagation velocity slowly decreases until reach a pinned state.
We carried out experiments in a one-dimensional Perot-Fabry passive Kerr cavity submitted to negative diffraction with a *4f* lens arrangement. The Kerr medium is a nematic liquid crystal thin film. The spatial forcing comes from the Gaussian profile of the laser beam and cylindrical lenses, which generate one-dimensional Gaussian beam. Fronts are generated using cavity under negative diffraction feedback. This last feature is achieved via *4f* lens arrangement that allows to obtain negative optical cavity length and consequently negative diffraction [5].
Under these conditions, experimental fronts are pinned after a nonlinear transitory propagating regime, showing a good agreement with the theory. The final state is a spatial localized structure. Numerical simulations of the Kerr cavity dynamics are consistent with the core trajectory analytical expression.

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P49 Exact analysis of stochastic bifurcation in ensembles of globally coupled limit cycle oscillators with multiplicative noise

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A solvable model for mean-field coupled limit cycle oscillators which are subjected to multiplicative noise is introduced [1]. The system is composed of two types of the oscillators with different native frequencies and under the influence of external white noise. We use a nonlinear Fokker-Planck equation approach which turns out to be noise level-free analysis. This approach enables us to derive the time evolution equations of the order parameters for the system in the thermodynamic limit without any approximation. We conduct a bifurcation analysis for the order parameters with changes in multiplicative noise strength. The structure of stochastic bifurcation involving synchronous-asynchronous phase transition between the two types of oscillators is discussed.

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Causality Information planes: a new tool for dynamical systems P50

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We highlight the potentiality of a special Information Theory approach in order to unravel the intrincates of nonlinear dynamics. Information quantifiers as the Shannon entropy, statistical complexity and Fisher information are functionals that characterizes the probability distribution $\mathbf{P}$ associated to the time series generated by a given dynamical system. The adequate way of picking up such distribution is achieved by the Bandt and Pompe methodology [1], which is one of the most simple symbolization techniques available and takes into account time – causality in the concomitant process. In this communication we introduce two representation spaces called causality entropy-complexity information plane $(\mathbf{H} \times \mathbf{C})$, which quantifies global features, as the presence of correlational structures [2] and, the causality entropy-Fisher information plane $(\mathbf{H} \times \mathbf{F})$ that measures local features [3]. These two informational planes become a new tool to characterize a time series generated by a dynamical systems or experimental measurements. We are able to distinguish between deterministic and stochastic dynamics [4]; and characterize phenomena, like different routes to chaos (period doubling, tangent and hopf bifurcations) as well differenciate between periodic, chaotic and quasiperiodic motions by appealing a rather surprising result: a *dynamic feature plane-topography map* $(\mathbf{H} \times \mathbf{F})$.

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Exchange rate volatility and economic calendar announcements: Some causal calculations P51

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By using news announcements extracted from the international economic calendar and real exchange rate of the three most important exchange indices, i.e., Euro/Dollar, Euro/Yen and Dollar/Yen, we investigated causality relations between both variables. Granger causality test, transfer entropy and symbolic transfer entropy were used in order to uncover to what extent forex indices were driven by news about the world macro-economy. News time series were constructed by using the release time, country currency source and the relative economic importance. By using this information from more than 50 countries world-wide, several time series were constructed with an average of 5000 news per year. Exchange rates time series were made of 10-minutes returns of spot real exchange rates. Both data sets were acquired from an online financial data provider. Five years (2008-2012) were analyzed independently one from the others. Different schemes were implemented in order to quantify news impact factors over exchange time series. Several aspects were studied and quantified in the present study, namely: Different effects between actual and predicted values and asymmetric ways of reactions to bad and good news.

P52 Directed communication-through-coherence during synchronous transients

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The mechanisms that mediate fast, flexible and precisely targeted switching between communication pathways in the brain are not yet fully understood. The communication through coherence hypothesis [1] states that dynamic coherence between oscillatory neural activity allows pliable pathway selectivity, allowing manifold functional connectivities to stem from fixed structural ones.

In this work we investigate through spiking network models how small motifs of interacting local populations can set their collective oscillatory activity into multi-stable phase-locked patterns. Due to spontaneous symmetry breaking [2], such dynamic states display out-of-phase locking in which a hierarchy of phase-leading and lagging areas emerge, despite symmetric rules for structural connections. We show that the inter-areal information flow is determined by this dynamics.

More specifically, we focus on systems consisting of two identically coupled randomly connected spiking networks of inhibitory and excitatory neurons with delays, heterogeneous parameters and realistic statistics. Each network can be tuned to obtain gamma band oscillations. The degree of synchronization smoothly varies across increasing local delayed inhibition.

In these symmetrically coupled networks, in the case of homogeneous input, we observe that out-of-phase locking is associated to anisotropic information flow with a dominant direction from leader to laggard areas, as revealed by a transfer entropy analysis of simulated LFPs. Moreover, we show that the degree of synchrony of the ongoing oscillations regulates the time the system spends in a fixed laggard-leader configuration. Thus, for nearly asynchronous states, windows of directed communication appear as short transients, during which the effective information flow shows the same anisotropic properties as for strong synchrony.

On the other hand, when the input each population receives is heterogeneous, small contributions can drive the dynamical system to have a preferred phase relation configuration which is not invariant under population exchange, meaning that the distribution of the phase relations is not symmetric anymore. This unimodal out of phase configuration translates in a nearly unidirectional communication channel. We explore how to restore the broken symmetry by introducing input modulations into the laggard community and study the probability of symmetry restitution as a function of the synchronization of the individual networks.

We finally explore how stimulus-like pulses can be used to select or switch the dominant directionality of information flow. We hypothesize that similar dynamic mechanisms might underlie the flexible switching of selective attention or prioritized selection of alternative computations within the same network.

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Distinct bifurcation mechanisms for binary decision making in biological systems P53

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Cell differentiation that occurs during multicellular development is commonly described as a sequential decision process in which, typically, precursor cells select between a finite number of predefined lineage-specific cell types. The binary decision outcome depends on both extracellular signals and various sources of noise. However, the manner how the interplay between signal and noise determines the timing and proportioning of cell-fate decisions presumably depends on the bifurcation mechanism underlying the appearance of two stable cell-fate states. The prevailing model for binary decision involves a pitchfork-type bifurcation that can arise in biochemical networks involving multiple positive-feedback loops [1, 2]. An alternative model has been recently proposed, based on bifurcations occurring at different phases of a limit cycle [3, 4]. The goal here is to compare decision properties based on these distinct bifurcation mechanisms by performing dynamic analysis of the related one-dimensional normal forms. We find that the oscillatory-based mechanism allows tunable cell-fate bias control in a noise-robust manner.

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Consistency through transient chaos P54

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We all expect from systems that react to their environment to be reliable, i.e. to respond in the same way to the same input signal. This requirement of reliability has been investigated, recently, in inanimate systems. For instance, it has been shown that chaotic optical systems show reproducible dynamics when subject to repeated sequences of the same input signal. However, an active reaction to the environment goes beyond this behavior. Inspired by the phenomenology observed in neuronal systems we require, besides reliability, that the dynamics is consistent. By this term, we refer to the ability of the system to react reproducibly during its transient evolution after the system has been perturbed in a pulsed manner by its environment. This property allows for a faster processing of information than passive systems, which have to reach more or less steady conditions before being ready to process the following perturbation. This type of processing dynamics also has the advantage of exploring a wider range of dynamical states during its transient evolution, permitting to process large amounts of information. This new requirement, involving in our case relaxation through transient chaos, thus allows for the efficient and reliable processing of information. We study theoretically and experimentally this phenomenon in very different systems. In particular, we show the behavior experimentally in a semiconductor laser with feedback. We also show it theoretically using the well-known Lorenz model, and also a more complex system which is physiologically inspired and describes the mesoscopic response of cortical columns, which are the information processing units in the brain. In this way, we unveil a possible new dynamical mechanism that may be mediating information processing in the brain.

P55 Observation of star-shaped surface gravity waves.

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We report a new type of standing gravity waves of large amplitude, having alternatively the shape of a star and of a polygon. This wave is observed by means of a laboratory experiment by vibrating vertically a tank. The symmetry of the star (i.e. the number of branches) is independent of the container form and size, and can be changed according to the amplitude and frequency of the vibration. We show that this wave geometry results from nonlinear resonant couplings between three waves, although this possibility has been denied for pure gravity waves up to now.

Computing chaotic eigenfunctions using localized wave functions over periodic orbits P56

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The efficient computation of the eigenfunctions of a system is one of the central problems in quantum mechanics since they completely describe the system's behaviour. This is particularly important in the case of heavy particle dynamics, close to the semiclassical limit or in the presence of classical chaos, where the eigenfunctions oscillate violently.
Most tradicional methods are based on the use of localized states in configuration space (DVR, Gaussian methods) or in the expansion of the Hamiltonian in a harmonic oscillator basis set.
Very recently, we have proposed a radically different approach to compute the eigenfunctions of a classically chaotic system using scar functions [1]. These scar functions are states strongly localized over the manifolds of the unstable periodic orbits [2]. This localization plays a central role in quantum chaos, which studies the correspondence between classical and quantum mechanics in nonintegrable systems [3, 4, 5, 6, 7]. Scar functions have, likewise, a very low energy dispersion, so they can be used to calculate the eigenfunctions of excited states in a small energy window.
In this communication, we apply the previous method [1] to calculate the eigenfunctions of the LiNC/LiCN isomerizing system [8]. This molecular system combines regions of regular and irregular motion at the same energy. We have successfully computed the 67 low-lying eigenfunctions of the system using a basis set formed by solely 74 elements. By measuring the participation ratios, we have demonstrated the excellent performance of our method since all the computed eigenfunctions are calculated as a combination of a small number of the basis elements, i.e. taking into account only the periodic orbits along which the semiclassical basis is constructed.

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P57 Reaction rate calculation for dissipative systems using invariant manifolds

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Transition state theory (TST) plays a central role in the study of chemical reactivity since it answers two fundamental questions: the identification of reactive trajectories and the computation of reaction rates [1, 2, 3]. TST is based on the existence of two different states (reactants and products) separated by an energetic barrier, the top of which forms a bottleneck for reactivity; the reaction takes place only if this barrier is crossed. The reaction rate can be computed by simply placing a recrossing-free dividing surface close to this barrier. Nevertheless, the dividing surface usually has recrossings, so the reaction rate is usually overestimated.

In the last years, the application of nonlinear dynamics techniques to study TST has provided a new insight into reactivity, by making a more geometrical description of the phase space. This has allowed the identification of strictly recrossing-free dividing surface in systems with many degrees of freedom [4, 5] as well as in harmonic systems that interact with their environment [6].

In this communication, we report on a new method that allows the identification of reactive trajectories exactly in anharmonic systems that interact with their environments without the need of any computationally costly numerical simulation [7, 8]. The method is based on the existence of geometrical structures (invariant manifolds) that act as separatrices of phase space. Further, we have succeeded in computing exact reaction rates; this has allowed us to calculate analytic corrections to the famous Kramer's formula due to the nonlinearities of the system.

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Inference in networks embedded in metric spaces P58

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We have introduced a method to infer significant structure in networks based on Expectation Maximization [1, 2], with the aim of applying it to networks whose nodes are embedded in a metric space. The method is used on different benchmark networks produced with a prior probability of connection between the nodes i and j. This probability is a function of the position coordinates of the nodes. By combining Expectation Maximization and Metric Multidimensional Scaling [3], we have recovered the given connection probability functions, the position of the nodes and the dimension of the underlying metric space from the benchmark networks. The quality of the inference is measured using mutual information, Hellinger distance and average distance to compare the inferred and the original connection probabilities. The results are shown for different system sizes, different number of links in the networks and sampling spatial scales. We have also checked that the method works well with different prior probabilities, including functions depending on the distance between nodes or other, more general, functions of node positions.

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P59 A study of spontaneous activity in modular neural networks made of neurons of different intrinsic dynamics

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Experimental evidence suggests that the architecture of the cerebral cortex is modular and hierarchical and that it can sustain collective activity in the absence of external stimuli [1]. Based on the firing pattern in response to intracellular current injection, cortical neurons may be classified into five different electrophysiological or dynamical classes [2]: regular spiking (RS), intrinsically bursting (IB), chattering (CH), fast spiking (FS) and with low threshold spikes (LTS). Cells from the first three classes are excitatory and from the latter two are inhibitory. In this work we use a hierarchical and modular network model made of excitatory and inhibitory neurons to study the role of the modularity level together with the intrinsic dynamics of the excitatory and inhibitory cells on the self-sustained network activity. Our hierarchical and modular network was constructed using a top-down method [1] starting with a random network of 1024 cells with connection probability of 0.01. The ratio of excitatory to inhibitory neurons was 4:1. Neurons were modeled according to the Izhikevich's formalism [3] with parameters adjusted to reproduce the firing behaviors of the five cell classes. Our model has two synaptic conductances, g_e and g_i, representing excitatory and inhibitory synapses. After a pre-synaptic event, these synaptic conductances are increased by constants Δg_e, Δg_i. Otherwise, they decay according to first-order linear kinetics with characteristic times $\tau_e = 5$ ms and $\tau_i = 6$ ms. We used the the modularization method of Wang et al. [1] with rewiring probabilities $R_i = 1$ and $R_e = 0.9$ to generate networks with up to four modularity levels. For each level we generated six networks given by the possible combinations of the three excitatory neuron classes with the two inhibitory classes. Each network was stimulated by white noise applied to all neurons for 200 ms followed by a period of 4800 ms without stimulation. We repeated this simulation for fifty realizations of each network and for different combinations of parameters Δg_e and Δg_i. For each network configuration we constructed a $\Delta g_e - \Delta g_i$ diagram giving the time of the last network spike. A time threshold of 4500 ms was defined beyond which the network was assumed as having self-sustained activity. Our results show that the duration of self-sustained activity increases with the modularity level. They also show that networks with excitatory cells of the RS class exhibit the largest range of self-sustained regimes and networks with excitatory cells of the CH class exhibit the smallest range of self-sustained regimes. We conclude that self-sustained activity in a neural network strongly depends on its modularity level and the intrinsic dynamics of its excitatory and inhibitory neurons.

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Networks of oceanic transport in the mediterranean P60

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We study transport phenomena in the oceans by using different tools borrowed from nonlinear dynamics and complex systems such as Complex Networks and Lagrangian Coherent Structures (LCS).
The aim is to search for connectivity patterns of sources and receptor spatial areas of different physical quantities that are advected by the geophysical flows. Give a sketch of this transport dynamic could represent a way to understand some general climatological issues related to the sea-atmosphere coupled system. Furthermore the opportunity of forecast, even if not so precisely, the real movements of water masses would be really important in other more applied fields such as pollutants dispersion and biology.
We have first applied this methodology to realistic numerical data of surface transport in the Mediterranean Sea, with a spatial resolution for the input of about 0.1 degrees. We simulate then the motion in this velocity field of more than 1,000,000 ideal fluid particles following their trajectories.
After this first step, in order to give a network-like interpretation, we have discretized the sea domain and we have constructed a transport matrix that describes the entity of transport between ideal cells in which the sea is divided.
Finally, by comparing this technique with with the LCS, we can characterize the relationship between barriers and avenues to transport with the linking properties of the constructed matrix.

P61 Experimental implementation of maximally synchronizable graphs

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Synchronization is one of the paradigmatic examples of how collective systems self-organize with the aim of achieving a common objective. Different strategies have been defined to enhance the synchrony of a network, ranging from age ordering of the nodes, pinning control, network rewiring or directly by the addition of nodes or links. The existence of a set maximally synchronizable graphs (MSG) was demonstrated analytically by Nishikawa et al. [1] and was based on the assignment of a link directionality together with an adequate adjustment of the link weights. This way, it is possible to reduce the eigenratio λ_N/λ_2 to its lower value, i.e. one, which guarantees the synchronization of the whole network once a critical value of the coupling strength σ_c is reached. Recently, the robustness of the MSG has been experimentally demonstrated with a set of $N = 4$ coupled optical systems organized in four different configurations [2]. Nevertheless, it has not been tested in large networks with complex structures.In this contribution, we test a experimental implementation of the MSG in large networks with complex topology. Specifically, we construct an electronic version of the Rössler system with chaotic dynamics and apply the methodology introduced by Pisarchik et al. [3] to create complex networks of N oscillators using only one single dynamical systems. As we will show, the MSG shows optimal performance when a certain critical coupling σ_c is reached. Three ingredients are crucial in order to achieve the synchronized state with the least effort: node ordering, directionality of the links and a normalization of the weights of the incoming links. We will also show that, given an initial network structure, there exist different configurations of their corresponding MSG that have equal performance.

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Review of cases of integrability in dynamics of low- and multidimensional rigid body in a nonconservative field **P62**

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In this activity the results are systematized both certain published earlier and obtained new on study of the equations of the motion of dynamically symmetrical four-dimensional $(4D-)$ rigid body which residing in a certain nonconservative field of the forces. Its type is unoriginal from dynamics of the real smaller-dimensional rigid bodies of interacting with a resisting medium on the laws of a jet flow, under which the nonconservative tracing force acts onto the body. Previously, the author showed the complete integrability of the equations of body planeparallel motion in a resisting medium under the conditions of streamline flow around when the system of dynamical equations has a first integral that is a transcendental (having essentially singular points in the sense of the theory of functions of one complex variable) function of quasi-velocities. At that time, it was assumed that the interaction of the medium with the body is concentrated on the part of the body surface that has the form of a (one-dimensional) plate. Later on, the plane problem was generalized to the spatial (three-dimensional) case where the system of dynamical equations has a complete tuple of transcendental first integrals. It was assumed here that the whole interaction of the medium and the body is concentrated on a part of the body surface that has the form of a plane (two-dimensional) disk. In this chapter the results which both were obtained earlier and now are pertained to the case when all the interaction of a medium with the body is concentrated on that part of the body surface that has the form of three-dimensional disk, herewith, the force interaction is concentrated in the direction which is perpendicular to this disk. These results are systematized and given in invariant form. Herewith, the additional dependence of the moment of the nonconservative force on the angular velocity is introduced. The given dependence can be wide-spread and on the cases of the motions in the spaces of higher dimensions.

P63 Synchronization of quasiperiodic oscillations by pulses action.

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The study of many-frequencies oscillations is a well-established topic and is widely discussed in a modern physics[1, 2, 3]. Despite such intensive research in this field the occurrence of the transition to chaos and the role of the dynamics involved in the degrees of freedom remain an open question to be investigated. Recently a series of new results concerning autonomous quasiperiodic dynamics and synchronization of quasiperiodic regimes were published. In paper [4] where was proposed and investigated an autonomous Radiophysics generator of quasi-periodic oscillations. The phenomena of doubling of tori, dynamics of coupled oscillators etc. have been studied for this generator. Recently in the paper [5] a model of an autonomous three-dimensional generator of quasiperiodic oscillations which is a "hybrid" of a generator of hard excitation and relaxation oscillator was suggested. The investigation of this system has revealed the possibility of quasi-periodic regimes [5].
The model which was introduced in [5] may be useful in theoretical, numerical and experimental studies of many aspects of quasiperiodic dynamics in autonomous systems and related topics. This system allows to consider the problem of synchronization of autonomous quasiperiodic oscillations by the external signal. Now the problem of synchronization of quasiperiodic oscillations studied to a much lesser extent than the synchronization of regular and chaotic regimes. Recently a number of new aspects of this problem are considered [6]. However, these studies are usually considered the resonant modes of synchronization of cycles on the torus. Our review suggests that in context of synchronization of quasiperiodic motions occur at least three problems: Synchronization of resonant cycle on the torus; Synchronization of quasiperiodic regime with incommensurate frequencies; Synchronization of the regime corresponding destructions invariant curve.
The generator of quasiperiodic oscillations is suitable for research all these problems. In the present paper we consider this system under action of periodic sequences of δ-functions:

$$\ddot{x} + (\lambda + z + x^2 - \beta x^4)\dot{x} + \omega_0^2 = A \sum \delta(t - nT), \dot{z} = \mu - x^2, \tag{1}$$

where A - amplitude, T - period of external force. The opportunity of realization of three-frequencies and two-frequencies torus for model (1) in case when autonomous system demonstrates quasiperiodic and periodic regimes are shown. The spectrum of Lyapunov exponents for system (1) was calculated. And in corresponding with it the construction of areas of two-frequencies and tree-frequencies torus on the parameter plane were revealed.
The work was been supported by RFBR, grant No. 12-02-31465.

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Adaptive POD-based ROMs to approximate bifurcation diagrams P64

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Construction of general bifurcation diagrams involving time dependent attractors may be computationally non-affordable, especially when the underlying physical system is modeled by partial differential equations. For dissipative systems, proper orthogonal decomposition (POD) can be used to compute low dimensional approximations allowing for flexible strategies to construct bifurcation diagrams. Thus, relying on the property that POD modes depend only weakly on time and possible parameters in the problem [1, 2], adaptive reduced order models (ROMs) can be developed in order to efficiently approximate bifurcations. In this context, we present a method that combines a time dependent numerical solver and a Galerkin system that is obtained via Galerkin projection of the governing equations onto some POD modes. At the lowest bound of the desired bifurcation parameter span, these modes are computed from some snapshots calculated by a short, generic run of the numerical code. Then, continuation is performed along the bifurcation diagram associated with the constructed Galerkin system, until the strategy detects that the POD manifold needs to be updated in order to guarantee a good approximation and avoid truncation instabilities. Updating is done by appropriately mixing the old modes with some other modes resulting from new, numerically computed snapshots, and leads to a new Galerkin system to be used for larger values of the bifurcation parameter. The proposed adaptive method is applied to the complex Ginzburg-Landau equation to approximate bifurcation diagrams involving periodic, quasi-periodic, and chaotic attractors, and turns out to be flexible, robust, and fast.

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The role of Pacific decadal oscillation in climate dynamics P65

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In recent years, the study of the Earth climate dynamics with complex networks tools has yielded new insights into climate phenomena, highlighting the highly complex pattern of interactions among the different elements that constitute our climate. A main challenge in the analysis of climate networks is the identification of their backbone, i.e., the truly relevant connections. Because climate networks are built over a regular grid of nodes representing geographical locations, the spatial proximity of the nodes implies that, when only the strongest correlations are considered, one obtains a network that is dominated by local connections. Here we propose a novel method of analysis that considers a type of data "coarse graining" employing teleconnection indices. The analysis reveals a clear role of the Pacific Decadal Oscillation (PDO) in the climate network connectivity. The PDO is a pattern of climate variability detected as surface water temperature oscillation in the Pacific Ocean, with a timescale of about 20 to 30 years, whose influence in the dynamics of our climate is well known, but that has not been previously found in climate networks.

P66 Multi-fractal relation in seismicity statistics: Data analysis of earthquakes around 3.11.2011

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It is essential for understanding the earthquake phenomenon to know the statistical laws of the seismic motion using the observation data. The seismic motion is characterized by some important statistical quantities such as frequency, magnitude and interoccurrence time of the seismic motion. The main theme of the conventional statistical laws is the identification of the distribution of the statistical quantities independently, but the relation between the quantities is not sufficiently considered. Our group have focused on the relation between the magnitude and interoccurrence time, and introduced the idea of the magnitude threshold. Recent study [1] reveals that there exist a universal relation associated with the magnitude and the interoccurrence time to lead a universal constant which does not depend on the magnitude. In this study, we investigated the universal relation using the earthquake data in around 3. 11. 2011, and found out the universal constant is drastically changed after the main shock (M:9.0) in 3.11.

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P67 CANCELLED. ~~Chimera States with Multiple Coherent Regions~~

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Chimeras-mixtures of coherent and incoherent structures that coexist in networks of nonlocally coupled oscillators-are of considerable current interest. We study a ring of nonlocally coupled phase oscillators with piecewise linear coupling, and examine the effect of changing the interaction on the existence of chimeras. In this system, chimeras are robust, arising from arbitrary initial condition and by modifying the coupling, we obtain states with more than one coherent (or incoherent) region. These multi-chimera states can have all coherent regions in-phase with each other or with alternating coherent regions in antiphase with each other. The proposed coupling can be used to design robust chimera states with any desired number of coherent (or incoherent) regions. The two-clustered chimera with in-phase and anti-phase coherent regions are analyzed in some detail.

Neural dynamics underlying spatio-temporal low-frequency fluctuations in the resting brain activity P68

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Spontaneous fluctuations in the fMRI blood-oxygen-level-dependent (BOLD) signal have been intensively investigated over past decade as a measure of "functional connectivity" between cortical regions of the human brain [1, 2, 3]. However, the question how these highly structured and robust patterns of the functional connections arise from the underlying neural dynamics and structural connectivity still remains poorly understood [4, 5]. In a typical fMRI experiment, functional networks are derived from the regions displaying correlated activity at low-frequencies ($\sim$0.1 Hz) even though the existent anatomical connections between them are largely unknown. It has been suggested that these correlated fluctuations reflect synchronized variations in neural activity of particular brain areas, which are dynamically coupled to one another. Here, we consider empirically derived resting state functional connectivity networks from fMRI data and build model by embedding neural oscillators into their 3D structures. We choose to model the local node dynamics by excitable FitzHugh-Nagumo neurons subject to different level of noise. We then simulate collective dynamics of the neural oscillators for a range of couplings, biophysically realistic time-delays and network topologies. We use various thresholds applied to empirically derived functional connectivity to influence network topologies and investigate emergence of functional connectivity in simulated data. We discuss role of global network behavior in shaping functional connectivity between distant cortical regions.

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P69 Stochastic models for climate reconstructions

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A plethora of methods exists to derive climate field reconstructions. While recent discussion has focused on the inference mechanism [1, 2], the stochastic model is at least as important. In contrast to methods that use large scale patterns over the full reconstruction domain, some recent methods [3, 4] implement a localised stochastic description. The local stochastic model used therein was based on simple assumptions, nevertheless it was able to skillfully reconstruct most of the climate variability in the pseudo proxy experiments.
In this contribution we show how such a model could be derived from available observational data or at least be validated. Using long transient climate model runs, we assess how the results of a Kramers-Moyal-Expansion change with data availability under a changing climate. Finally, we estimate the error introduced into the climate field reconstruction by deliberately using a too simple stochastic model.

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P70 Analysis of cerebral inflammation MRI data by means of complex networks

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While complex network theory has widely been used to analyze the structure of different biomedical data sets, Magnetic Resonance Imaging data are not included in this group; this is mainly due to the lack of information about the temporal evolution of the system, which prevents the reconstruction of functional networks. In this contribution, we propose a novel method for the analysis of MRI data, based on the application of a *parenclitic* network representation technique. Following this framework, nodes represent single (or groups of) measurements, and pairs of them are connected according to the distance from a predefined reference model. This network reconstruction approach is here applied to the analysis of MR images of mouse brains suffering from cerebral inflammation. By analyzing the resulting network topologies, it is possible to detect which are the features best discriminating patients and control subjects, thus shedding light on the mechanisms behind the disease.

The topological model for a qubit: Quantum states in the sheaf framework P71

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We consider some generalization of the theory of quantum states, which is based on the analysis of long standing problems and unsatisfactory situation with existing interpretations of quantum mechanics. We demonstrate that the consideration of quantum states as sheaves can provide, in principle, more deep understanding of some well-known phenomena. The key ingredients of the proposed construction are the families of sections of sheaves with values in the proper category of the functional realizations of infinite-dimensional Hilbert spaces with special (multiscale) filtrations decomposed into the (entangled) orbits generated by actions/representations of internal hidden symmetries. In such a way, we open a possibility for the exact description of a lot of phenomena like entanglement and measurement, wave function collapse, self-interference, instantaneous quantum interaction, Multiverse, hidden variables, etc. In the companion paper we consider the machinery needed for the generation of a zoo of the complex quantum patterns during Wigner-Weyl-Moyal evolution together with constructive algebraic control.

Periodic dynamics of intrinsically motivated learning P72

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We investigate the effects of intrinsic motivation on the dynamics of the learning processes. The intrinsic motivation here is one's desire to learn not because it may cause some tangible benefits in the future, but due to the inherent joy obtained by the very process of learning [1]. We propose a dynamical model of intrinsically motivated learning based on Sato-Crutchfield continuous-time reinforcement learning framework. In virtually all learning models developed previously in game theory and cognitive science the learning subject is assumed to act rationally in achieving the ultimate goal — to maximize the cumulative reward gained during the learning. We challenge this approach by assigning a piece of non-rationality to the learning agent, who is biased by the desire to select the actions she has little information about.

We study a simple example of a single agent adapting to unknown environment. The agent behavior is governed by two stimuli. The traditional objective stimulus is to maximize the total payoff collected throughout the process. The subjective one is irrational — to engage in active learning as much as possible, because the very learning process is enjoyable for the agent. We show that the agent biased in such way does not stick to the optimal strategy of behavior, in contrast to the rational learning agent [2]. Instead, the agent preference continuously varies in an oscillatory way. Through the simple numerical analysis of the model we demonstrate that the intrinsic motivation leads to the instability of the learning dynamics.

Our results give evidence to the fact that the intrinsic motivation in particular and the bounded rationality in general may cause the significant changes in the dynamics of single- and multi-agent learning systems. Therefore, we argue that the effects of human intrinsic motivation in particular and the bounded rationality in general may be of exceptional importance in complex sociopsychological systems and deserve much attention in the formal models of such systems.

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P73 Human control of dynamical systems: Insights from virtual stick balancing

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In the present paper we aim to shed light on some general properties of the human control behavior. We analyze probably the simplest example of a human-controlled system — an inverted pendulum. Human stick balancing has been investigated widely from various perspectives; studies based on both real-world and virtual experiments are available (see, e.g., [1]). However, attention has been mainly paid to the in-depth understanding of the mechanical and physiological aspects of human control. We propose a complementary approach and emphasize the existence and importance of some psychological issues as well.

Consider a hypothetical dynamical system controlled by a human operator whose purpose is to stabilize the system near an equilibrium point. We hypothesize that in a wide class of such systems the operator does not react to small deviations from the equilibrium, though these variations are clearly recognized by her perception. In other words, the operator is comfortable with the deviations of a small amplitude. The operator perceives the desired end-state in a fuzzy way: she treats equally any point from a certain neighborhood of the equilibrium one. This is in fact a manifestation of the human fuzzy rationality phenomenon [2]. The dynamical trap model has been developed previously to capture these effects [3]. Here we provide the experimental evidence of the dynamical trap model: the subjects of the experiment on virtual stick balancing demonstrate the features of behavior predicted by the model.

In our study the statistical properties of the stick motion controlled by human actions have been discovered to be notably similar for all the participants of the experiments. First, the obtained phase portraits match the structure of the phase trajectories produced by the dynamical trap model. Second, the stick angle distribution has bimodal shape, exactly as predicted by the model. Finally, the stick angular velocity distribution is found to be exponential, not Gaussian as it may be expected. This fact also corresponds well to the findings of the previous work on the dynamical traps. Even more surprising is the fact that the found patterns of operator behavior remain the same for both the “slow” stick (when the task is easy and the operator acts in a relaxed manner) and the “fast” stick (when balancing requires full concentration and high skill).

The present work provides a strong evidence to the hypothesis that human control behavior in a whole class of dynamical processes is subjected to the effects of fuzzy rationality. Our findings may have impact in a wide range of disciplines, such as traffic dynamics, human factors and ergonomics.

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Global stability and local bifurcations in a two-fluid model for tokamak plasma P74

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We study two-fluid description of high and low temperature components of the electron velocity distribution of an idealized tokamak plasma. We refine previous results concerning local bifurcations and global stability of the steady-state solutions. We prove global stability outside a parameter set of possible linear instability. For a large set of parameters, we prove the primary instabilities for varying temperature difference stem from the lowest spatial harmonics. We show that any simple bifurcation due to these modes is a supercritical Andronov-Hopf bifurcation, which yields stable periodic solutions in the form of travelling waves. In the degenerate case, where the instability region in the temperature difference is a point, we prove that bifurcating periodic orbits form an arc of stable periodic solutions. We provide numerical simulations to illustrate and corroborate our analysis. These also suggest that the stable periodic orbit, which branches-out the steady-state, undergoes additional bifurcations.

Reconstruction of causality from short environmental time series P75

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We address the reconstruction of causal relations among marine environmental processes. In particular, we are dealing with time series containing information about abundance and presence of dissolved organic matter (DOM) in the North Sea. DOM is composed of organic molecules that are mainly produced by biological growth and microbial degradation, forming a large carbon reservoir in the global oceans. So far, little is known about the plethora of organic molecules and the mechanisms driving the generation and degradation processes. The lack of knowledge of relevant time scales underlying the biotic and abiotic processes together with the shortness of the time series ($\sim$ 100 sampling points) are critical issues regarding the statistical inference of causality. Checking causality on several time scales leads to multiple testing and related corrections hamper the detection of statistically significant relations. For our analysis we utilize the renormalized partial directed coherence (rPDC), a frequency-domain causality measure based on the model class of vector autoregressive (VAR) processes [1]. Considering the stated issues, we empirically asses the statistical significance of rPDC values for short time series using surrogate data. Furthermore, we evaluate the efficiency (error statistics) of the rPDC by reconstructing artificial networks of VAR processes of given order, length, dimension and average number of couplings from sampled multivariate time series.

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P76 Collective Chaos and Chimera States in pulse-coupled neural networks

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We study the dynamics of two symmetrically coupled populations of identical leaky integrate-and-fire neurons characterized by an excitatory coupling. Upon varying the coupling strength, we find symmetry-breaking transitions that lead to the onset of various chimera states as well as to a new regime, where the two populations are characterized by a different degree of synchronization. Symmetric collective states of increasing dynamical complexity are also observed. The computation of the finite-amplitude Lyapunov exponent allows us to establish the chaoticity of the (collective) dynamics in a finite region of the phase plane. The further numerical study of the standard Lyapunov spectrum reveals the presence of several positive exponents, indicating that the microscopic dynamics is high-dimensional.

PT5: Plenary talk

A new metrics for the economic complexity of countries and products

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Measuring intangible nonmonetary values is a crucial element in economics because its comparison with the monetary performance can reveal new information on the hidden potential of a country which is the fundamental element for future growth. Here we consider the COMTRADE dataset which provide the matrix of countries and their exported products. According to the standard economic theory the specialization of countries towards certain specific products should be optimal. The observed data show that this is not the case and that diversification is actually more important. Specialization may be the leading effect in a static situation but the strongly dynamical globalized world market suggests instead that flexibility and adaptability are essential elements of competitiveness as in biosystems. The crucial challenge is then how to turn these qualitative observations into quantitative variables. We introduce a new metrics for the Fitness of countries and the Complexity of products which corresponds to the fixed point of the iteration of two nonlinear coupled equations. The nonlinearity is crucial because it represents the fact that the upper bound on the Complexity of a product is given by the less developed country that can produce it [1]. This and other differences make our metric completely different from the one of Hidalgo and Haumann who first tried to address this question. We discuss the conceptual and practical advantages of our approach which represents a concrete tool for a realistic and testable description of these ideas. The information provided by the new metrics can be used in various ways. The direct comparison of the Fitness with the country GDP gives an assessment of the non expressed potential of the country. This can be used as a predictor of GDP or stock index. The global dynamic shows, however, a large degree of heterogeneity which implies that countries which are in a certain zone of the parameter space evolve in a predictable way while others show a chaotic behavior. This heterogeneous dynamic is also outside the usual economic concepts. It is also possible to evaluate risk and compare it with the standard ratings. Finally this new approach may be interesting for planning of the industrial development of a country.

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PT6: Plenary talk

Model studies of electron transfer and conduction mediated by solitons in 1D and 2D crystal lattices

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First I shall present a model of soliton-like excitations in lattice chains/circuits/layers with units interacting with Morse interactions. Then, by adding external excess electrons, using the tight binding approximation (TBA), I shall show the formation of bound states between such charges and the soliton excitations, thus defining the "solectron" quasiparticle, in a sense that generalizes the (textbook) "polaron" concept of Landau, Pekar, Fröhlich,... and the "electro-soliton" of Davydov. I shall also comment on "electron pairing" and the formation of bi-solectrons (two strongly correlated electrons in momentum space and in real space with due account of Coulomb repulsion and Pauli's exclusion principle). Adding Langevin stochastic sources to the mixed classical-quantum dynamics of the system, I shall illustrate the "long lasting" robustness and hence "practical" stability of the solectrons to moderate levels of heating (up to ambient temperature in bio-molecules). The solectron moves in general with supersonic velocity though its actual velocity depends, e.g., on the strength of electron-lattice/phonon/soliton interaction. Possible applications of the theoretical predictions include a novel form of electron transfer (ET) in polymers like poly-di-acetylene (PDA and related) crystals, synthetic DNA and Ga-As or LiNbO3 (SiO) layers.

MS16: Control of synchronization in delay-coupled networks

Time-delayed couplings arise naturally in many complex networks, for instance in optical, electronic, or mechanical systems, due to finite signal transmission and processing times, and memory and latency effects. Examples are provided by delayed coupling or delayed feedback in coupled lasers, neural networks, sensor networks, or electronic circuits. Since time delays can either induce instabilities, multistability, and complex bifurcations, or suppress instabilities and stabilize unstable states, they can be used to control various patterns of synchronization like zero-lag synchronization, cluster or group synchronization, amplitude or oscillator death.

Organizers: *E. Schöll and A. Zakharova*

Generalized synchronization properties of delay-coupled semiconductor lasers

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Synchronization of coupled laser systems has found considerable interest over recent years. Lasers have proven to be excellent testbed systems to study general synchronization phenomena. Moreover, synchronisation of coupled lasers has been demonstrated to be attractive for applications, ranging from encrypted communication to key distribution. A particularity of coupled semiconductor lasers is, that the coupling delays among the lasers cannot be neglected. This results in characteristic dynamical instabilities and particular synchronization properties. Not least, because of these laser systems, delay-coupled networks have become a very active research field [1]. In recent years, significant inside has been gained into the influence of the coupling topology and the particular properties of the dynamical nodes. However, most of the investigations have concentrated on the particular case of identical synchronisation and global stability considerations. In this contribution, we concentrate on the question, what the consequences of intermittent loss of synchronisation are and how such systems can still be utilised. Moreover, we illuminate the properties of generalised synchronisation. We discuss how one can gain insight into the nature of this state. We present a method, by which the attractor of delay-coupled lasers in the generalized synchronized state can be approximated by segments of trajectories of the delayed feedback system and vice versa. The implications for the dimensionality of the corresponding attractors will be discussed. In addition, we demonstrate that the limitations of synchronization due to strong or weak chaos also leave their fingerprints in experiments on generalized synchronization in semiconductor lasers.

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Symmetry-breaking oscillation death in nonlinear oscillators with time-delayed coupling

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The collective behavior in coupled nonlinear systems and networks of oscillators is of great current interest. Besides various synchronization patterns, special attention has recently been paid to oscillation suppression. There are two types of oscillation quenching known in the literature: amplitude and oscillation death. Although the distinction between amplitude death and oscillation death is not always obvious, the underlying mechanisms are crucially different. Amplitude death appears as a result of the stabilization of an already existing steady state that is unstable in the absence of coupling. On the contrary, oscillation death occurs due to a newly created stationary state which is a result of symmetry breaking of the homogeneous steady state. Therefore, amplitude death is represented by a symmetric homogeneous steady state, whereas oscillation death is characterized by an inhomogeneous steady state. It has also been shown that amplitude death can occur in time-delayed systems. In contrast to this, the relation between symmetry breaking of the system in presence of time-delay, and thus the formation of inhomogeneous steady state, i.e. oscillation death, under these conditions has not been tackled. Moreover, it is known that time-delayed couplings arise naturally in many types of networks, for instance in coupled lasers, neural networks, electronic circuits, or genetic oscillators, due to finite signal transmission and processing times, and memory and latency effects. Additionally, time-delayed coupling and feedback represent an important aspect of control in various technical and natural systems. Thus, we propose and characterize here the conditions under which oscillation death can be observed in time-delayed systems. Using a paradigmatic model of coupled Stuart-Landau oscillators, we define the coupling structures for which symmetry breaking of the homogeneous steady state occurs, and study in detail how oscillation death can be controlled by introducing time-delay in the system. We also discuss the importance of time-delayed amplitude death and oscillation death from application viewpoint in physics and biology. Oscillation death is especially relevant for biological systems, since it provides a mechanism of cellular differentiation.

Patterns of synchrony and death in networks with time delays

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I will present some recent results on how time delays shape synchronization patterns in networks of coupled oscillators. Understanding the effects of delays suggests the possibility of exploiting them to control network behavior. I will indicate the possibilities and limits of obtaining complete synchronization, or patterns of phase-locked solutions, as well as attaining a desired oscillation frequency. A range of dynamical behavior involving phase relations and frequencies can be rigorously derived in models of phase oscillators, with implications extending to weakly coupled limit-cycle oscillators. For stronger coupling, the delays can also affect the amplitude of the solutions. An extreme case is the so-called amplitude death, where all oscillations die to zero as whole network moves to a constant equilibrium solution. More interestingly, it turns out that stability and synchrony can co-exist in the network, giving rise to a new type of behavior we call partial amplitude death. In this state, a group of oscillators are quenched whereas the remainder of the network exhibits (in-phase and anti-phase) synchronous oscillations.

Control of synchronization patterns in neural-like Boolean networks

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Synchronization patterns have been observed in neural time-delayed networks of directed ring topologies. We study these networks experimentally using artificial neural networks built with autonomous Boolean logic gates and heterogeneous link time delays [1]. We observe a phase transition in the network synchronization dynamics depending on the scaling of the refractory period compared to the link time delays and the delay heterogeneities. In the first case, the cluster synchronization patters can be altered when the refractory period and link time delays are comparable. In the second case, when the refractory period is smaller than the average heterogeneity, the network can not sustain synchronization patterns. This mechanism allows us to control neural network dynamics by adjusting the refractory period of only a small number of neurons with the largest in-degree, which play a key role in the organization of the global dynamical properties of the network. Our work may have important implications for synchronization phenomena in biological neural networks because it is known that the refractory period can be affected by hormone blood concentrations in the brain.

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MS17: Localized structures of light in dissipative media II

In recent years considerable progress has been made in understanding the properties of nonlinear localized structures of light (often called optical solitons) in dissipative systems. Due to their unique diffraction properties, such dissipative media, has very promising applications in modern technology. The two mini-symposiums we propose involve theoretical and experimental talks by leading groups working in nonlinear optics and laser physics. The purpose of the two mini-symposiums to bring together contributions of researchers working on mathematical, physical, and technological aspects of localized structures, and thereby to present an overview of the state of art in the formation and the characterization of localized structures. The following topics related to the formation of localized structures in dissipative systems will be covered: PART II: Cavity solitons in VCSELs with saturable absorber Light Propagation and Localization in periodic media Cavity Solitons in VCSELs with frequency selective feedback Localized structures in discrete nonlinear systems

Organizers: *M. Tlidi, K. Staliunas and K. Panajotov*

Spontaneous spatial structures in cold atoms due to opto-mechanical coupling

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Spontaneous symmetry breaking is responsible for pattern formation and self-organization in many areas of nature and science. Ensembles of cold atoms coupled to a light field constitute an interesting and highly controllable system to study self-organization. We demonstrate both theoretically and experimentally the spontaneous formation of transverse hexagonal patterns in a sample of cold Rb atoms excited by a single laser beam with mirror feedback. These patterns manifest in both atomic density and light intensity, and are of adjustable length scale. The optomechanical effect arises from the dipole force on the atoms which exists in a non-uniform light field. Intensity perturbations lead to atomic density perturbations, and hence, with appropriate feedback, to instability and self-organisation into hexagonal patterns and other structures. We analyze the competition between electronic nonlinearities and optomechanical effects in cold atoms, and show that the latter become dominant as the temperature is lowered. Indeed the instability is already present in a very simple model without electronic nonlinearity, and where the atoms are modeled as otherwise-free particles subject only to optical forces, i.e. without viscous damping. The simplicity of this optomechanical mechanism for spontaneous symmetry breaking suggests that it can be found, and exploited, in many other atomic and optical configurations and we will discuss examples, such as a ring cavity [1], and prospects, such as optomechanical soliton formation.

[1] E. Tesio, G.R.M. Robb, T. Ackemann, W.J. Firth and G.-L. Oppo. *Phys. Rev. A* **86** 031801(R) (2012).

Strong non-local coupling stabilizes localized structures

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We investigate the effect of strong non-local coupling in bistable spatially extended systems by using a Lorentzian like kernel. This effect through front interaction drastically alters the space-time dynamics of bistable systems by stabilizing localized structures in one and two dimensions, and by affecting the kinetics law governing their behavior. We derive an analytical formula for the front interaction law in one dimension and show that the kinetics governing the formation of localized structures obeys to a power law. To illustrate this mechanism we consider two models, a prototypical bistable system governing by a Nagumo-type equation (often used in population dynamics), and nonlinear optics model describing a ring cavity red filled with a left-handed material. Numerical solutions of the governing equations are in close agreement with analytical predictions.

Towards temporal cavity solitons in semiconductor ring lasers

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The control of transverse localized structures in semiconductor microcavities has reached an impressive maturity during the last years, progressively shifting from proof of concept to advanced control and realization in monolithic devices. In this context one can separate systems in two broad categories depending on the presence or absence of phase symmetry; in the latter case, localized structures can be phase locked to an external forcing. While this exact situation has been extensively explored in the transverse domain, most of the observations of dissipative structures localized along the propagation dimension have been realized in systems with phase symmetry, ie in laser systems in a mode-locking regime [1]. Indeed, the observation of phase locked localized structures in time domain has been only very recently reported, based on an experiment in a fiber ring cavity with external forcing [2]. In this contribution, we will describe our approach aimed at bridging laser mode-locking and phase locked localized structures. We will present experimental and numerical observations realized on an externally forced ring semiconductor laser.

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Slowly evolving vector solitons in mode locked fibre lasers

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Polarization dynamics in lasers (including gas, solid state, semiconductor, dye and fiber lasers) have been intensively studied for more than two decades in the context of various applications in fibre optic communication, fibre optic sensors, material processing (cutting, welding etc.) and nanophotonics (manipulation of asymmetric particles). In such systems two laser modes with the same longitudinal and transverse spatial patterns and different polarization states, frequencies, and amplitudes interact through the gain sharing, phase- and amplitude selective nonlinear processes (Kerr nonlinearity) and in-cavity components (polarizers, polarization controllers etc.). As a result of the interaction, different polarization patterns have been found including polarization chaos. In fibre lasers, due to long cavity length and wide gain bandwidth, typically, a large number of modes are generated. This leads to stochastic polarization dynamics as a result of spontaneous mode-locking. However, implementation of passive or active mode-locking techniques results in suppression of stochastic dynamics and so regular dynamics in the form of dissipative solitons were observed. Dynamics and stability of solitons on a longer time scale (at the level of thousands of cavity round trips) is well governed by the theory of dynamical systems leading to different "attractors" (fixed point, periodic, quasi-periodic, chaotic). The vectorial nature of the DSs has been observed in Fast Polarization Rotating or Locked Vector Solitons (PRVS and PLVS). In PLVS pulses are locked to a fixed elliptically polarized state while PRVSs have demonstrated different types of anti-phase dynamics for cross polarized SOPs with a period of a few round trips. Note that information about the phase difference between orthogonal SOP was missed and so observed polarization dynamics of VS's can't be related to any polarization attractor. Unlike this, we report herein to the best of our knowledge a first complete experimental and theoretical characterization of new families of vector solitons in a carbon nanotube mode-locked fibre laser with anomalous dispersion laser cavity. We have found a new type of vector solitons with locked and precessing SOPs for fundamental, multipulse and bound states solitons operations on a time scale of thousands round-trips. The observed polarization attractors might be a key to the future enabling technologies of secure communications, trapping and manipulation of atoms and nanoparticles and vectorial control of magnetization.

MS18: Longwave and multiscale pattern formation

The phenomenon of pattern formation has been extensively studied during several decades. The major success has been achieved in the exploration of patterns created by short-wave instabilities, which are characterized by a well-defined critical wavelength near the threshold of their onset and governed by some versions of a generic (Ginzburg–Landau) amplitude equation. However, there exists a variety of problems where the patterns have significantly different length scales, and their description is much more diverse. Specifically, the Ginzburg–Landau equation is not efficient in the case of longwave instabilities typical for thin layers. A list of challenging problems in this field is wide: a nonlinear interaction of shortwave and longwave patterns; the description of the nonlinear dynamics of patterns created by a longwave oscillatory instability; patterns emerging under a temporal modulation of the governing parameters, to name but a few.
The present minisymposium will expose some recent achievements in solving the latter kind of problems. Modulated surface waves produced by horizontal vibrations are described in the lecture by Jose Manuel Vega. Patterns generated by longwave oscillatory instabilities are considered in the lecture by Sergey Shklyaev et al. The lectures by Pierre Colinet and Uwe Thiele are devoted to different aspects of a long-wave pattern formation caused by evaporation.

Organizers: *A. Nepomnyashchy and S. Shklyaev*

Instabilities of perfect periodic large-scale wavy patterns

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Instability of perfect periodic patterns is a challenging problem in pattern formation with a variety of applications in diverse fields. This problem is especially interesting for two-dimensional wavy patterns, where intriguing structures consisting of standing or traveling waves with definite phase shifts can emerge. Near the instability threshold, the analysis can be performed based on a set of appropriate Ginzburg-Landau equations.

In general, even such reduced analysis needs massive computations, but it can be significantly simplified in the case of a longwave instability. However, while making computations easier, the application of the longwave approximation results in some mathematical complications; in particular, the nonlinear dynamics is governed by a set of non-local equations. Although near the stability threshold these non-local equations can be transformed to conventional Landau equations describing perfect periodic solutions, perturbation analysis and pattern selection are both more involved than in the case of a shortwave instability.

One has to distinguish between three types of disturbances of periodic patterns that have to be treated differently. Instabilities with respect to internal perturbations, with the wavevectors belonging to the same Fourier lattice as the base state, can be tracked using the results of [1, 2]. External perturbations with the wavevectors significantly different from those of the base state, can be divided into two classes, simple and resonant ones. The disturbances of the former class are formed by a single traveling wave or a pair of counter-propagating waves. The disturbances of the latter class comprise a larger number of waves interacting with the base state; this type is closely related to the instability on a superlattice. Finally, a large-scale modulation of the pattern with wavevectors close to those of the base state but different from them, cannot be reduced to any particular case of external perturbations, and it should be studied separately in a different way.

We consider all these types of perturbations for a general problem with the following features characteristic for longwave oscillatory instabilities in systems with a conservation law: (i) the dispersion relation is quadratic; (ii) only gradients of amplitude functions, rather than functions themselves, contribute to the nonlinear dynamics. The obtained general stability criteria are applied to the particular physical problem of Marangoni convection in a binary liquid with the Soret effect [3].

Our numerical investigation shows that Alternating Rolls computed on a square lattice are stable with respect to both internal and external perturbations, and can be either stable or unstable with respect to modulations depending on the problem parameters. No oscillatory hexagonal patterns stable with respect to modulations have been found.

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Pattern formation in horizontally vibrated rectangular containers

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The behaviour of vibrated fluids is of great interest in a variety of fields and can be very complex. Vertical vibrations are the most studied case because the basic (unexcited) state is quiescent in a co-moving reference frame. Horizontal vibrations are generally less straightforward to treat and have received less attention, especially in the limit in which the vibrating frequency is large compared to that of the fist capillarity-gravity sloshing mode. In this case, harmonic surface waves are always excited and, beyond a critical acceleration, subharmonic cross-waves are also triggered by a (harmonic) oscillatory bulk flow, which is slowly varying in space and extends over a distance comparable to the container depth. The exciting mechanism is analogous to that responsible for Faraday waves in vertically vibrated containers; the main difference is that the oscillatory pressure field is not uniform but dependent on distance from the end-walls. The resulting cross-waves are not perpendicular to the vibrating end-walls, as standard cross-waves produced by partially immersed wave makers typically are. A linear theory will be presented to calculate the threshold amplitude that compares well with experiments. As a byproduct, we obtain a general linear amplitude equation that governs pattern selection in containers of arbitrary cross-section.

Long-wave description of the dynamics of evaporative pattern deposition

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After reviewing a number of experiments on evaporating and dewetting thin layers of suspensions and solutions we first briefly discuss microscale discrete (KMC) and continuous (DDFT) approaches to describe the occuring evaporative dewetting fronts and their instabilities [1]. Second we present a mesoscale hydrodynamic (thin film) model that allows us to discuss the self-pinning depinning cycles of a contact line related to the emergence of periodic deposit structures in evaporative dewetting [2]. We discuss the local and global bifurcations that trigger the deposition of regular structures and further analyse them employing a simplified Cahn-Hilliard-type model for related phenomena in Langmuir Blodgett transfer [3].
Finally, the limits of the presented approaches are laid out and a 'thermodynamic' re-formulation of the mesoscopic hydrodynamic model is proposed as a gradient dynamics based on an underlying free energy. It allows for a systematic incorporation of several additional physical effects as, e.g., solute-solvent decomposition and solute-dependent wettability resulting in an entire class of consistent long-wave models [4].

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Complete titles/links can be found under www.uwethiele.de/publ.html

Pattern formation in drying thin liquid films

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The spontaneous Bénard-Marangoni (BM) patterns induced by evaporation of a pure liquid layer are studied experimentally and theoretically. A thin volatile liquid layer placed in a cylindrical container is left free to evaporate into air at rest under ambient conditions. The time evolution of the temperature field in the layer, representative of the pattern organization resulting from the BM instability, is visualized using either an infrared (IR) camera, or a Schlieren optical set-up. Due to evaporation, the liquid layer thickness monotonically decreases, at a rate which can be tuned by controlling the global evaporation rate. This continuous quench of the system forces a rapid growth of the number of convection cells, hence leading to an increase of the average pattern wavenumber with time. Surprisingly, both the dimensionless wavenumber and the concentration of defects (mostly chains of pentagons-heptagons) at a given supercriticality do not depend on the speed of change in the pattern. Even though this might seem natural for sufficiently small quenching speed (quasi-static, or adiabatic regime), it is not really clear why this is still the case at the moderate speeds studied here. Moreover, it is shown that the wavenumber adjustment can proceed in two ways: splitting (or nucleation) of new cells, and drift of coherent “islands" of cells from the periphery, resulting in a compression of the pattern. While drift/compression seems to dominate at low quenching speeds, splitting/nucleation is the main mechanism at faster evaporation rates. In addition, inspection of the cells topological arrangements shows that nucleation (and collapse of cells, though it plays a minor role in the pattern genesis) appears more likely at the defects positions (more precisely, the cells splitting most often are heptagons) than in areas consisting of islands of quasi-perfect hexagonal cells. Yet, the proportion of these defects (e.g. number of pentagons and of heptagons divided by the total number of cells) seems independent of the mechanism, splitting or drift, allowing the wavenumber adjustment. On the theoretical point of view, it is first shown that a simple model allows to predict the critical film thickness below which convection patterns disappear (i.e. the BM instability threshold). In addition, ramped long-wave models of convection are numerically investigated in order to gain deeper insight into the dynamics of wavenumber adjustment. Although studied here for Bénard convection, it is believed that these mechanisms of cellular pattern genesis should be generic for many physical systems where the preferred wavenumber is continuously varied by some external constraint.

MS19: Interacting populations on social and ecological networks

Our society use a hundred of new ways to interact with the others: tweeter, facebook, ... But the rules of interaction in our society are the same as the species in Nature. This workshop aims to bring together scientists of both ecology and social science so that both may better understand the challenges faced by each other and how best they may collaborate.

Organizers: *R. M. Benito and J. C. Losada*

Modeling bipartite networks with nestedness

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Classic papers [1, 2] declare that the plant-animal interactions have played a very important role in the generation of Earth's biodiversity. The importance of mutualism, the beneficial interaction between two species, for biodiversity maintenance can be supported by the fat more than 90% of tropical plant species depend on animals for the dispersal of their seeds. These interactions are best represented by weighted mutualistic bipartite networks [1]. Those networks have been repeatedly reported to show particular properties as truncated power law distribution of the degree or a nested structure. While several metrics for measuring nestedness in weighted mutualistic networks have been proposed in the past few years [3], most dynamic models in the literature aim to reproduce just the binary nested structure ignoring the development of the weighted pattern [4, 5]. We introduce a simple dynamic model based on a modified preferential attachment rule for bipartite networks. Our model simulates the growth of a mutualistic network generating weighted interaction matrices that we compare with empirical data from several real biological networks [6]. The resulting network shows a power-law degree distribution in both cases: plants and animals. Furthermore, the model reproduces accurately the nestedness behavior. In a different study concerning bipartite networks, we have proposed a new model modifying the classical logistic equation with additional terms to take into account interspecies interactions. We have developed a model of mutualism based on the aggregation of benefit for each species in its equivalent growth rate:

$$
\begin{aligned}
\frac{dN_j^a}{dt} &= r_{eq_j}^a N_j^a - |r_{eq_j}^a| \frac{N_j^{a\,2}}{K_j^a} \\
\frac{dN_l^p}{dt} &= r_{eq_l}^p N_l^p - |r_{eq_l}^p| \frac{N_l^{p\,2}}{K_l^p}
\end{aligned}
\tag{1}
$$

where the superscripts stand for each of both class of species. With these equations, we have built a binomial stochastic simulator for the study of system dynamics. It allows the introduction of external perturbations such as step increases in mortality by plagues, removal of links between species due to evolution, or overlapping of a predator foodweb.

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Monitoring Twitter. Tools for social graph visualization and automatic text classification

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Market and society are strongly manifested in the Internet, specially in social networks. Twitter allows to their more than 200 millions users to post/read messages, known as tweets. Users can also reply and re-post these tweets from different types of devices such as computers, tablets or smartphones, transforming Twitter in one of the most important social networks where news and opinions spreads quickly around the world. In this presentation we show two different tools for real-time Twitter analysis.
The first, called User Network, corresponds to an interactive and real time graph of user "talking" about a topic. This network is characterized by a metric for influence, called Social Network Influence ($SNIscore$), for users belonging to the graph. The $SNIscore$ for the user u considers: (i) the number s of users connected directly to them, (ii) the size g of the set of users belonging to the graph to which u belongs, (iii) the strategic-topological position ρ of u in the graph, (iv) the number f of Followers and Friends of u in Twitter and (v) the influence probability, corresponding to the actions (tweets) performed by users of g that are a consequence of the actions performed by u. This measure is based on an influenceability probability model proposed by [1]. The joint probability of u influencing each neighbour $v \in g$ can be defined as follows,

$$p_{u(g)} = 1 - \prod_{v \in g} (1 - p_{u,v}) \tag{1}$$

where $p_{u,v}$ is the influence probability of u on v. Having said that, the $SNIscore$ for the user u is defined as,

$$\mathrm{SNI}_u = \tau(\rho \times g) + \pi(f) + \alpha(p_{u(g)} \times s) \tag{2}$$

where τ, π and α are free parameters of the model that control three dimensions in SIN score: Topological, Twitter profile and Activity.
The other tool, are two network-based algorithms designed for natural language processing. Using word networks (i.e., graphs build out of words co-occurrences in tweets) one of the algorithms infers the principal idea behind a set of tweets constructing the most probables word chains extracted from those networks according to the frequency of words and relations in the set. The other algorithm classify automatically tweets in different sentiment categories (positive, negative and neutral) mapping unclassified tweets on training word networks (i.e., co-occurrence word networks constructed using set of tweets previously classified in a sentiment category by a human). Thus, the lower cost obtained for reconstructing an unclassified tweet in a trained network determines its category according to the following equation,

$$C \sim \frac{\hat{l}}{P} \tag{3}$$

where C is the cost for reconstruction, $\hat{l}$ the mean geodesic distance between two words of the unclassified tweet in the trained network and P the number of words pairs of the unclassified tweet in the trained network.
The results obtained display a higher precision (F-masure) in comparison to traditional algorithms used in text classification such as Naive Bayes or Support Vector Machines (SVMs).

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Efficiency of human activity on information spreading on Twitter

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Nowadays, the online social networks have become the ideal source of user generated data to characterize and model, human behavioral patterns [1]. On daily basis, several commercial, political and social organizations are increasingly exploiting these communication tools to disseminate updates on their respective fields. The deeply understanding of such spreading processes is crucial to design better strategies and get optimal outcomes from the network potential.
In this work, we propose a method to characterize and model the user efficiency to influence the emergence and growth of information cascades. The model we propose is based on a biased Independent Cascade Model [2] on networks. We use this model to study the impact of different factors on the spreading process, such as the individual behavior and the underlying substratum, as well as capturing and reproducing the main properties of the user efficiency to influence.
We capture these properties, by means of a quantitative analysis of the structural and dynamical patterns emergent from human interactions, during a Venezuelan political protest on Twitter, as a case of study. For this matter we have analyzed over 400,000 messages, downloaded from the Twitter severs, using the search API.
Our findings suggest that the user efficiency to transfer information is strongly conditioned to the underlying topology, where messages are propagated. In the sense, the highly connected nodes efficiently cause remarkable collective reactions, than the large majority of users, whose efforts are much higher than the results gained.
We conclude that although individuals may present psychological complexities and differences, the resulting patterns are a reflection of the dynamical rules behind the spreading process constrained to the available mechanisms.

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Meritocracy in the age of networks

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A system is said to be meritocratic if the compensation and power available to individuals is determined by their abilities and merits. A system is topocratic if the compensation and power available to an individual is determined primarily by his or her position in a network. Here we introduce a simple agent based model to study the effects of networks in meritocracy. The model is perfectly meritocratic for fully connected networks but becomes topocratic for networks as sparse as those observed in society. Here individuals can produce and sell content -which we abstract as cultural content, such as books, films or music- and distribute the content produced by others. The production and distribution of content define two channels of compensation: a meritocratic channel where individuals are compensated for the content they sell and produce, and a topocratic channel, where individual compensation is based on the number of shortest paths that go through them in the network. We solve the model analytically and numerically for random and scale free networks, obtaining individuals payoff and the resulting income distributions. We conclude that the sparsity of networks represents a fundamental constraint to the meritocracy of modern societies.

MS20: Dissipative solitons

Solitons, solutions which maintain their shape and velocity after colliding with each other, were introduced, almost fifty years ago, in integrable nonlinear systems. Later, this term soliton has been generalized to refer solitary waves in non-integrable and non-conservative systems.
In non-conservative (dissipative) systems, stable localized solutions have been found experimentally in systems as diverse as surface reactions, binary fluid convection, sheared electroconvection in liquid crystals, non-linear optics, etc. These dissipative solitons result from the balance through an energy exchange with the environment in presence of nonlinearity and dispersion (and/or diffraction). The dissipative soliton concept is based on the notions of soliton, nonlinear dynamics and dissipative systems.
This Minisymposium Dissipative Solitons aims to inform and share knowledge (both experimental and theoretical) of this very active research field.

Organizers: *O. Descalzi*

Rare transitions in the carbon monoxide oxidation on Palladium(111) in ultra-high-vacuum conditions

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Our work focuses on the physical and mathematical modeling of the rare transitions observed experimentally in the CO oxidation on Pd(111) under ultra-high-vacuum conditions (UHV), reported by Stefan Wehner's lab. These transitions, induced by weak noise created by mass flow controllers, make the state of the system (the coverage of the Pd crystal) switch from one stable steady state to a different stable steady state. These back and forth transitions are observable for very long periods of time. What is peculiar about these transitions is the timescales: very long periods of time without major changes in the state of the surface, followed by sudden, unexpected transitions, that are fast but still considerably slower than the underlying microscopic phenomena. As one can verify from the PEEM images, some transitions are genuine spatio-temporal phenomena involving nucleations and propagation of fronts. These transitions are perfect instances of what is known as 'rare events': large macroscopic changes that occur intermittently at timescales much slower that the underlying microscopic processes. Rare event theory explains the main features of the most probable transition paths.

Traveling convectons in binary mixtures

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Binary fluid mixtures with a negative separation ratio heated from below exhibit steady spatially localized states called *convectons* for supercritical Rayleigh numbers. With no-slip, fixed temperature, no-mass flux boundary conditions at the top and bottom stationary odd and even parity convectons fall on a pair of intertwined branches [1, 2] that form the backbone of the snakes-and-ladders structure of the so-called pinning region. These branches are connected by branches of asymmetric localized states called *rung* states that drift. When the boundary condition on the top is changed to Newton's law of cooling, the midplane symmetry is broken. As a consequence, the even parity convecton branch splits into branches, one with upflow at midpoint and the other with down flow at midpoint, the odd parity convectons start to drift and their branch breaks up and reconnects with the branches of asymmetric rung states [3]. We explore using numerical continuation the dependence of these changes on the associated Biot number, and compare and contrast the results with a related study of the Swift-Hohenberg equation by Houghton and Knobloch [4].
We use the results to identify stable traveling convectons and we employ direct numerical simulations to study collisions between them. The collisions are highly inelastic, and are accompanied by radiation of energy. A traveling convecton can either attract or repel a stationary convecton depending on whether the facing roll rotates in the same direction as the incoming roll or in the opposite direction. In all cases studied the width of the final state exceeds the sum of the widths of the incident convectons as the collision excites the nucleation of additional rolls on either side.

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Explosive dissipative solitons

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With the use of numerical simulations of the one dimensional complex- quintic Ginzburg-Landau equation, we studied the apparition of chaotic explosive localized solutions and their behavior at long time scales. We also studied the stabilizing effect on the explosive solutions of the intrapulse Raman scattering.

Localized hexagonal patches of spikes on a layer of ferrofluid

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The study of stationary spatially localized states in dissipative systems has regained much interest, because there are several open problems [1]. A particularly well defined experimental model system is a layer of magnetic liquid subjected to a magnetic field oriented normally to the fluid surface. When a critical threshold of the field is surpassed, the flat layer becomes unstable due to a transcritical bifurcation and a hexagonal pattern of liquid spikes emerges, a phenomenon known as Rosensweig instability [2]. Applying a local perturbation in the hysteretic regime localized spikes were generated and studied experimentally [3, 4]. Their range of stability was confirmed numerically [5].
Even without a local perturbation localized spikes and a set of localized hexagonal patches have been detected in a highly viscous ferrofluid, when the system is pushed to the vicinity of the unstable branch of the homogeneous pattern [6]. These findings may be related to a snaking curve situated in the neighborhood of the unstable branch, as recently investigated for the case of the two-dimensional Swift-Hohenberg equation [7]. In our experiment we conduct a detailed scan of the phase space spanned by the pattern amplitude and the control parameter of the magnetic induction. We compare the experimentally observed patches with numeric results obtained y solving the Young-Laplace and Maxwell equations.

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PT7: Plenary talk

The Fragility of Interdependency: Coupled Networks & Switching Phenomena

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Recent disasters ranging from abrupt financial "flash crashes" and large-scale power out- ages to sudden death among the elderly dramatically exemplify the fact that the most dangerous vulnerability is hiding in the many interdependencies among different networks. In the past year, we have quantified failures in interconnected networks, and demonstrated the need to consider mutually dependent network properties in designing resilient systems. Specifically, we have uncovered new laws governing the nature of switching phenomena in coupled networks, and found that phenomena that are continuous "second order" phase transitions in isolated networks become discontinuous abrupt "first order" transitions in interdependent networks [1, 2]. We conclude by discussing the network basis for under- standing sudden death in the elderly, and the possibility that financial "flash crashes" are not unlike the catastrophic first-order failure incidents occurring in coupled networks. Specifically, we study the coupled networks that are responsible for financial fluctuations. It appears that "trend switching phenomena" that we uncover are remarkably independent of the scale over which they are analyzed.

This work was supported by DTRA, ONR, and NSF, and was carried out in collaboration with a number of colleagues, including T. Preis (Mainz & ETH), J. J. Schneider (Mainz), S. Havlin & R. Parshani (Bar-Ilan U), S. V. Buldyrev (Yeshiva U), J. Gao & G. Paul (BU).

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PT8: Plenary talk

Title TBA

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Abstract TBA

PT9: Plenary talk

Mechanism of dissipation in turbulent quantum fluids at ultra low temperatures

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At very low temperatures, for example below 1 degree Kelvin for Helium, the classical viscosity is practically zero. Yet, preparing a state of flow it becomes turbulent and it decays in time. I will discuss the physical mechanisms that are responsible for this inviscid dissipation: weak turbulence of Kelvin waves on quantized vortex lines and sound emission during vortex reconnection. I will stress in particular some recent progress on analytical solutions for both these mechanisms.

PT10: Plenary talk

Distinguishing signatures of determinism and stochasticity in spiking complex systems

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I will present a method to infer signatures of determinism and stochasticity in the sequence intensity dropouts of a semiconductor laser with optical feedback, which resemble neuronal spikes. The method uses ordinal time-series analysis to classify inter-dropout-intervals (IDIs) in two categories that display statistically significant different features, one being consistent with waiting times in a resting state until noise triggers a dropout, and the other, with dropouts occurring during the return to the resting state, which has a certain deterministic component. The method can be used for the analysis of real-world data, such as neuronal recordings of inter-spike intervals (ISIs), or data generated by complex systems such as inter-event times of user activity in social communities, where signatures of deterministic underlying dynamics can be obscured by the presence of noise. The method is computationally simple to implement and the data requirements can be adapted to the analysis of small and large data sets.

MS21: Dynamics of multistable systems

The phenomenon of multistability has been found in almost all areas of science and nature, ranging from optical to chemical and biological systems. This mini-symposium aims to discuss recent advances in studying multistability in coupled oscillators and lasers. Over many years the study of coupled nonlinear oscillators has been a hot topic in nonlinear science, since it provides a simple but efficient model for a better understanding of collective behaviors. In general, the appearance of a multitude of attractors a particular system depends on its most important characteristic parameters, such as, dissipation, coupling type and strength, delay time, amplitude and frequency of parametric excitation, and noise. In coupled oscillators, multistability is often related with the loss of synchronization that results in the coexistence of synchronous and asynchronous states. A particularly interesting dynamics appears when a specific coupling leads to the emergence of infinitely many attractors. Such an extreme multistability is closely related to the emergence of a conserved quantity and the appearance of generalized synchronization between the two systems. Special attention is given to suppression of oscillations by coupling, in which the amplitude reduces to zero, bringing the system to a homogeneous steady state (amplitude death). Another important feature is the creation of a new stable inhomogeneous steady state (oscillation death) that may share the phase space with the oscillation regime. Oscillation death has been observed in chemical and electronic experiments and in many model simulations, mostly in regular two-dimensional systems. Moreover, the coexistence of oscillation-death generating inhomogeneous regimes with synchronous chaotic oscillations has been found. Understanding how oscillation death appears and its compatibility with other regimes is an essential part of control dynamics. For the last decade, a lot of research has been devoted to the development of control techniques of multistable systems. It is shown that multistability can be efficiently controlled by filtered noise, which gives preference for some attractors and suppresses the others. Sometimes, stochastic perturbations lead to the emergence of a stable fixed point and intermittent switches between coexisting states. Furthermore, color noise can result in giant pulses referred to as rogue waves in a multistable system. These intriguing effects are replicated by lasers.

Organizers: *A. Pisarchik*

Study of multistate intermittency and extreme pulses by low-pass filtered noise in a fiber laser

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Clear evidence of rogue waves in a multistable system is revealed with an erbium-doped fiber laser driven by harmonic pump modulation. We demonstrate numerically and experimentally that a low-pass noise filtering can control the probability for the appearance of a particular state. The results of numerical simulations with the use of a three-level laser model display good agreement with experimental results. The mechanism for the rogue wave formation lies in the interplay of stochastic processes with multistable deterministic dynamics. Low-frequency noise applied to a diode pump current induces rare jumps to coexisting subharmonic states with high-amplitude pulses perceived as rogue waves. The probability of these events depends on the noise filtered frequency and grows up when the noise amplitude increases. The probability distribution of spike amplitudes confirms the rogue wave character of the observed phenomenon. We find the existence of a particular noise amplitude for which a particular periodic orbit appears more frequently than for other amplitudes.

Noise-induced bistability and on-off intermittency in mutually coupled semiconductor lasers

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A noise-induced transition from a monostable to a bistable regime is numerically demonstrated with the modified Lang-Kobayashi model. A stable fixed point and low-frequency fluctuations coexist for a very strong coupling within a certain range of spontaneous emission noise. The experiments with two identical mutually coupled semiconductor lasers confirm this theoretical prediction. For smaller intrinsic noise, intermittent switches between low-frequency fluctuations and stable emission are experimentally studied when the lasers pump currents are subject to common Gaussian white noise. The time series analysis shows power-law scalings typical for on-off intermittency near its onset, with critical exponents of -1 and -3/2, respectively for the mean turbulent length versus the noise intensity and probability distribution of the laminar phases versus the laminar length. The frequency spectrum analysis reveals a -1 power-law scaling for the signal-to-noise ratio versus the noise intensity.

Inhomogeneous stationary and oscillatory regimes in coupled chaotic oscillators

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Over many years the study of coupled nonlinear oscillators has been a hot topic in nonlinear science, since it provides a simple but efficient model for a better understanding of collective behaviors. Special attention has been given to suppression of oscillations by coupling, which either reduces the amplitude to zero, bringing the system to a homogeneous steady state ("amplitude death"); or creates a new stable inhomogeneous steady state ("oscillation death") that may share the phase space with the oscillation regime. Oscillation death has been observed in chemical and electronic experiments and in many model simulations, mostly with regular 2-dimensional systems. Coupled identical chaotic oscillators were studied with the focus on the ways to a synchronous regime, without considering the possibility of quenching of chaotic oscillations via the appearance of OD. In most coupling schemes, OD is not actually realized; however, we managed to find the coupling matrices that lead to OD and are not exotic. The conditions for OD are model dependent: pairs of Lorenz oscillators have to be coupled by conjugate or negative coupling, whereas just standard diffusion of one appropriate component is sufficient for a pair of PR oscillators. It is of principle importance that, similar to regular oscillators, OD and other OD-generated inhomogeneous regimes may coexist with synchronous chaotic oscillations. The dynamics of transition to OD is essential for understanding the ways of its formation and the compatibility with other regimes. The dynamics of linearly coupled identical Lorenz and Pikovsky-Rabinovich (PR) oscillators are explored numerically and theoretically. We concentrate on the study of inhomogeneous stable steady states ("oscillation death" (OD) phenomenon) and accompanying periodic and chaotic regimes that emerge at an appropriate choice of the coupling matrix. The parameters, for which OD occurs, are determined by stability analysis of the chosen steady state. Three model-specific types of transitions to and from OD are observed: (1) a sharp transition to OD from a nonsymmetric chaotic attractor containing random intervals of synchronous chaos; (2) transition to OD from the symmetry-breaking chaotic regime created by negative coupling;(3) supercritical bifurcation of OD into inhomogeneous limit cycles and further evolution of the system to inhomogeneous chaotic regimes that coexist with complete synchronous chaos. These results may fill a gap in the understanding of the mechanism of OD in coupled chaotic systems.

Extreme multistability and synchronization in coupled systems

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Many systems in nature are characterized by the coexistence of different attractors for a given set of parameters. Examples for such behavior can be found in different fields of science ranging from mechanical or chemical systems to ecosystem dynamics. One of the system classes where this kind of behavior appears are coupled systems where multistability is often related with the loss of complete synchronization leading to the coexistence of synchronized and nonsynchronized attractors. A particularly interesting dynamics appears in two identical coupled systems when a special coupling is applied. The coupling leads to a dynamics characterized by the emergence of infinitely many attractors. We show that this extreme multistabiity is closely related to the emergence of a conserved quantity and the appearance of generalized synchronization between the two systems. The conserved quantity leads to a confinement of the dynamics to a complicated synchronization manifold in state space on which the dynamics take place. The state space appears to be "foliated" into such manifolds each of them characterized by a certain value of the conserved quantity and a certain attractor living in this manifold. Since the conserved quantity can take any real value, we obtain infinitely many such manifolds and, hence, infinitely many coexisting attractors. Furthermore we develop at general principle how to design the coupling between any two nonlinear systems to achieve extreme multistability. Finally we demonstrate that this phenomenon can also occur when the two systems are not identical but possess a certain parameter mismatch.

MS22: Stochastic population dynamics

The dynamics of populations subject to demographic and environmental fluctuations is a subject of current interest in Theoretical Biology where recent progress has been substantial - using asymptotic and diffusion approximations for the stochastic dynamics.

Organizers: *B. Mehlig*

Metapopulation dynamics on the brink of extinction

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We analyse metapopulation dynamics in terms of an individual-based, stochastic model of a finite metapopulation, using the number of patches in the population as a large parameter. This approach does not require that the number of individuals per patch is large, neither is it necessary to assume a time-scale separation between local population dynamics and migration. Our approach makes it possible to accurately describe the dynamics of metapopulations consisting of many small patches. We focus on metapopulations on the brink of extinction. We estimate the time to extinction and describe the most likely path to extinction. We find that the logarithm of the time to extinction is proportional to the product of two vectors, a vector characterising the distribution of patch population sizes in the quasi-steady state, and a vector – related to Fisher's reproduction vector – that quantifies the sensitivity of the quasi-steady state distribution to demographic fluctuations. We compare our analytical results to stochastic simulations of the model, and discuss the range of validity of the analytical expressions. By identifying fast and slow degrees of freedom in the metapopulation dynamics, we show that the dynamics of large metapopulations close to extinction is approximately described by a deterministic equation originally proposed by Levins (1969). We were able to compute the rates in Levins' equation in terms of the parameters of our stochastic, individual-based model. It turns out, however, that the interpretation of the dynamical variable depends strongly on the intrinsic growth rate and carrying capacity of the patches. Only when the carrying capacity is large does the slow variable correspond to the number of patches, as envisaged by Levins. Last but not least, we discuss how our findings relate to other, widely used metapopulation models.

Large velocity fluctuations of stochastic invasion fronts

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Invasion fronts determine the speed of many important dynamic phenomena such as chemical reactions, epidemic outbreaks and biological evolution. The position of an invasion front fluctuates because of the shot noise of individual reactions. What is the probability to observe a certain displacement of the noisy front that is considerably smaller or larger than that of its deterministic counterpart? The answer strongly depends on whether the front propagates into a metastable or unstable state, and I will review recent theoretical progress in both cases [1, 2, 3, 4]. Most of the progress is based on a WKB theory which assumes many individuals in the front region. In this theory the most likely configuration of the system, for a given front displacement, is encoded in a special trajectory of the underlying effective Hamilton mechanics –a field theory. In some cases this special trajectory is a traveling front solution of the corresponding field theory. For fronts, propagating into unstable states, the leading contribution to the probability density of observing anomalously large front displacements comes from a few fastest particles running ahead of the front. For such fronts anomalously large displacements are much more likely than anomalously small ones.

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Fluctuations as a source of population stability

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We discuss how strong fluctuations may have a stabilizing effect on population size or gene fixation. The phenomena is a close analog of Coleman-Weinberg effect in high energy physics, explaining stability of false vacua against tunneling decay. We present a paradigmatic two species model, where strong fluctuations in the relative abundance serve as a source of stability for total combined population.

Stochastic evolutionary game dynamics

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In the past decade, researchers in evolutionary game theory have become increasingly interested in using stochastic processes to model dynamics. In particular, stochastic dynamics allow addressing the problem of equilibrium selection by focusing on the average abundance of strategies. This issue is for example of relevance in the context of the evolution of cooperation and punishment, which represents the most popular application of game theoretic models. An analytical approximation that is particularly powerful is weak selection, which is based on neutral evolution as a reference case. This also provides a natural connection to the powerful tools of population genetics.

MS23: Time series and causality networks

An aspect of the analysis of multivariate time series that has gained much attention in the last years is the inter-dependence of the observed variables. In many applications, the observed variables are considered as representatives of the underlying dynamical subsystems and the objective is to get insight onto the dependence structure of the global dynamical system. The starting point is to select appropriate measures of inter-dependence, information flow, or as commonly termed Granger causality, and often nonlinear measures are found to be more appropriate. Such measures determine the connectivity between each pair of observed variables and by assigning the variables to nodes and the estimated Granger causality to the respective connections, one can form causality networks. Causality networks constitute a mapping of the system's inter-dependence structure and can reveal system properties, distinguish between different system regimes, track the system evolution and identify structural changes.
This session will cover some recent advances in the methodology of Granger causality and information flow, as well as the study of causality networks, focusing also on real-world problems, ranging from physiology to finance. The invited papers will present implications of having synchronous observations of many variables and propose solutions (Small et al, Wan & Jensen), as well as improvements in measuring Granger causality and information flow (Papana et al, Diks & Wolski). They will also study causality network structure under different conditions, e.g. Attempting to discriminate modes of playing mucic from electroencephalogram connectivity analysis (Wan & Jensen). Brain analysis will also be conducted at micro scale using local fields potentials and investigating synchrony of neural oscillations (Small et al), while other presentations will focus on causality in economics, e.g. Weather's effect on grain market (Diks & Wolski).

Organizers: *M. Small and D. Kugiumtzis*

Nonlinear Granger causality: Guidelines for multivariate analysis

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Diks and Panchenko (2006) propose a new statistical approach to the nonlinear Granger causality testing, which aims to correct for the over-rejection problem observed in the original methodology developed by Hiemstra and Jones (1994). Nevertheless, both papers focus on the bivariate case only, leaving the more general higher-dimensional world unexplored. Our new methodology provides a simple and intuitive nonlinear Granger causality test that might be easily applied in the multivariate settings. To our best knowledge, this is one of the first attempts to formalize this kind of reasoning and equip it with the asymptotic theory. It is hard to mention all the possible applications, however, we are going to apply the test to the US grain market where the relationship between the prices is, to a large extent, affected by the weather forecasts. The new methodology allows us to correct for that phenomenon and to get a clear view US grain market behavior.

Investigating causal relationships – application to financial time series

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Some well-known causality tests and measures are reviewed and applied in order to detect and interpret the emerging relations between financial variables. The discrimination of direct and indirect causal effects and the determination of the nature of the couplings (linear it vs. nonlinear) is also discussed. In order to attain the stationarity of the financial time series, the returns of the original data are used. The causality tests and measures considered are namely the Granger causality index and the conditional Granger causality index [1], the partial Granger causality [2], the causality tests of Diks & Panchenko [3], the causality test of Kyrtsou & Labys [4], the transfer entropy and the partial transfer entropy [5], the symbolic transfer entropy and partial symbolic transfer entropy [6], the mutual information on mixed embedding and the partial mutual information on mixed embedding [7]. The statistical significance of the measures is assessed with randomization test, whenever is not theoretically known. The effectiveness of the different bivariate and multivariate measures, along with the consistency of the results from the different causality measures is discussed.

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Quantifying network interaction and synchrony in multi-electrode recordings

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Multi-electrode array data presents a unique challenge for data analysis ñ how can one properly infer interactions between electrode sites from recorded time series data? While many methods exist to measure (some version of) correlation and hence infer connectivity, this is only a partial solution. To arrive at a more useful answer, one needs to properly account for various complicated systems of interactions (where a common source may drive multiple regions leading to spurious connectivity directly between those driven regions), and also the inherently localized features of the system (electrodes have a definite location, and diffusion will play a role in artificially raising the level of correlation between spatial nearby measurements). We demonstrate a generic solution to these problems for a particular physiological system. Network oscillations in the gamma frequency range ($\sim$30-80 Hz) are thought to be important in the formation of neural circuits during development, cognition, plasticity, and encoding of sensory signals. Here, we study the dynamics of gamma oscillations in acute slices of the somatosensory cortex from juvenile mice (P8-12). Bursts of gamma oscillatory activity lasting a few hundred milliseconds could be initiated by brief trains of electrical stimulations simultaneously delivered at multiple locations. Local field potentials (LFPs) were recorded using multielectrode arrays allowing a spatial-temporal characterization of the oscillations. Numerical techniques where then applied to measure the global strength and synchrony of the gamma oscillation activity over time. Analysis of the phase of oscillations, current-source density analysis and dynamical measures of synchrony were used to show how different sites in cortex become synchronized.

EEG Analysis of information flow during music performance

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We analyse EEG data recorded on musicians and listeners during the performance of music. The music is either performed as "strict" or "let go". The first mode is in principle a "mechanical" retention of the music the second is with full interpretation and emotional expression. We use information theoretic measures of information flow (in particular MIME and variations of this approach) to establish a directed network of flow between the entire set of EEG electrodes of all musicians and listeners. We use this network to look for differences between the two modes of playing music.

MS24: Temporal cavity solitons and fronts in photonic crystal fiber resonators

Femtosecond pulse compression in Non linear photonic crystal fiber

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In recent years, especially with the development of photonic crystal fibers with special dispersion and nonlinear properties, pulse compression of optical pulses draws a lot of attention. These fibers enable input pulse with lower peak power to form high-order solitons for the purpose of femtosecond pulse-width compression. In this work, many sections (60 cm – 2.2 m) of non linear photonic crystal fibre with zero dispersion wavelength of 1040 nm have been used for ultra-short pulse compression for different durations of 460 to 620 fs. The split-step Fourier algorithm is used to investigate the pulse compression process in this PCF according to optical properties of this medium in terms of high non-linearity and Group Velocity Dispersion. We numerically investigate the generation of soliton pulses of different orders in this photonic crystal fiber (PCF) to realize the compression of used short pulses. The initial pulse of 1 ps is compressed in 2.5 m of PCF to a duration of 460 fs with a compression factor of 2.17 and a quality factor compression of 0.31. We could have a higher degree of compression using a higher order soliton. At the length of 1.6 m, the initial pulse is compressed from 1 ps to 304 fs with a compression factor of 3.3 significantly better than that obtained with a soliton of order 2, the compression quality is equal to 0.36. At 1 m length, we obtained the best compression results of the initial pulse of 1 ps to 221 fs with a compression factor of 4.5 and with the coefficient of compression quality equal to 0.339.

Dynamics of supercontinuum generated in photonic crystal fiber ring configurations

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Flexible control of dispersion properties in photonic crystal fibre (PCF), combined with potential high nonlinearity, have led to spectacular spectral broadening of input pulses. The main requirement for effective broadening is to pump close to the zero-dispersion of the waveguide. Several schemes have been demonstrated, using various pump pulse durations from the fs [1] up to CW [2]. Dual-wavelength pumping of fibres with two-zero dispersion points has also been proposed [3]. These supercontinuum sources find many applications in, e.g., spectroscopy, frequency metrology and optical coherence tomography. Shot-to-shot noise as well as the coherence properties of the resulting spectrum are important parameters of the source [4]. Furthermore, another approach, employing a feedback loop to tailor the noise characteristics of the source, has recently been proposed [5].
In the talk we will discuss the use of endlessly single mode PCF in a synchronously pumped ring cavity. The pump laser is a Yb:KYW oscillator delivering 140 fs, 13 nJ pulses at a repetition rate of 75 MHz. The central wavelength (1042 nm) is close to the zero-dispersion wavelength (1058 nm) of the PCF in the normal dispersion region. Experimentally, we can easily adjust both the frequency detuning of the ring-cavity as well as the pump pulse-energy, to observe a plethora of dynamical phenomena ranging from simple period-n oscillations to highly complex chaotic behaviour. The different regimes can be most easily studied within a bifurcation diagram of the output pulse energy vs. cavity detuning, which also allowed us to determine and quantify the influence of timing jitter [6]. Our system can be theoretically modelled using a discrete map where the generalized nonlinear Schrödinger equation is used to relate the field envelope A_{n+1}(z=0, t) at the start of the (n+1)th round trip to its shape A_n(z=L, t) after the nth round trip (fibre length L):

$$A_{n+1}(z=0,t) = \sqrt{1-R}\,A_n(z=L,t+\tau_{\text{eff}}) + i\sqrt{R}\,A_{\text{pump}}(t) \qquad (1)$$

where R is the reflectivity of the beam splitter used for pumping the ring cavity and the effective delay includes both cavity detuning and timing jitter induced by the laser source.

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Linear wave packet structure and rogues waves statistics in nonlinear Schrödinger equation

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During the last years, the number of publications related to rogue waves (RW) have considerably increased. Hence, this concept which originally comes from hydrodynamics, is now a hot topic of research in many fields including optics, capillarity, superfluidity, atmosphere or microwaves. Many of these fields have jointly a minimal model which governs RW dynamics: the nonlinear Schrödinger equation. In this context nonlinear coherent solution seeded by amplification of noise, have been shown to display many of RW characteristics. In addition, it is also known that RW dynamics is highly sensitive to initial conditions and the presence of a reflection symmetry breaking in the system. That is, in this study we have considered the linear stage of the process leading to RW generation by mean of a localized initial condition in the nonlinear Schrödinger equation including third order derivative. We have evaluated analytically the asymptotic evolution of this initial condition by mean of the Green function. The obtained wave packet structure reveals a band gap in the instantaneous frequency spectrum. Combining this result with RW statistics we give an optimal region of parameters for their excitation.

Dark temporal cavity solitons in photonic crystal fiber resonators

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During last decade, the study of confinement of light in photonic crystal fiber resonators has attracted a considerable attention from both fundamental as well as applied point of views [1]. In particular, near zero dispersion wavelengths, high order dispersion effects play a central role in this system. The study of a fourth order chromatic dispersion effect reveals that the existence of a second modulational instability that allows for the stationary state to restabilize at large powers. It has been shown that at the first threshold, there exist a degenerate modulational instability where two separate frequencies appear simultaneously [2]. It has also been shown that close to this degenerate bifurcation, beating can be localized and contain a finite number of slow modulation. More recently, we have shown that fourth order dispersion effects allow all-fiber cavity to exhibit dissipative dark localized structures in anomalous dispersion regime, whereas this was impossible without the high order dispersion [3]. These structures exhibit a homoclinic snaking behavior [3].
In this communication, we consider a simple all-fiber photonic crystal cavity synchronously pumped by a coherent injected beam. We show that the third order dispersion drastically affects the dynamics of this device. We show that the third order induces a motion of dark temporal cavity solitons with a constant velocity. However, the width of the dissipative pulses emerging from the modulational instability is not affected by the third order effect, as well as the threshold associated with modulational instabilities.

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MS25: Extreme events

Rare event prediction in stochastic systems with multiple time scales

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Many stochastic systems of physical interest possess dynamics which occur over multiple time scales. Such systems present unique difficulties in the analysis of large fluctuations, since the multiple time scales interact with the stochasticity to affect transition rates in the dynamics. For slow-fast systems singular perturbation theory may be applied to guide analysis, while noisy systems are better understood through tools from statistical mechanics. In this work, a method to predict the rate of occurrence of rare events is developed for systems that exhibit *both* noise and slow-fast dynamics. We use a WKB approximation to model the probability of rare event occurrence due to large fluctuations. The resulting equations generate a Hamiltonian that models the interaction of the state and the most likely noise force to induce a rare event. The equations of motion of the state and its conjugate momenta are singularly perturbed; to analyze them, the vastly different time scales are leveraged in order to reduce the dimension and predict the dynamics on the slow manifold. The resulting constrained equations of motion may be used to directly compute rare event probabilities. To test the method, a noisy, damped Duffing oscillator with three equilibrium points (two sinks separated by a saddle) is analyzed. After a long time spent in one sink, noise may “kick” a trajectory past the saddle and into the other basin of attraction. The predicted switching time exponent between states is computed using the action by integrating along the heteroclinic connection in a 4-dimensional phase space. The general scaling of the switching exponent as a function of system parameters is shown to agree well with numerical simulations. Moreover, the dynamics of the original system and the reduced system via center manifolds are shown to agree very well over sufficiently long time scales. The authors gratefully acknowledge the Office of Naval Research for support.

Extreme fluctuations and long-time memory of large scale wind power production

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The fluctuations of electrical energy, generated by wind turbines, reflect the interaction between the turbulent wind field and a complex technical system. In this talk we study time series of the integrated wind power production of a large number of spatially distributed wind energy converters. The aim is to characterize the fluctuations of wind power production by means of multi-time statistics. By testing the Markovian properties of the time series, we investigate the memory of the stochastic process describing the fluctuations. This leads to a description of the data in terms of Langevin equations. We also check the consistency of our findings with results on the fluctuations of surface-layer wind velocity data measured at different locations.

CANCELLED. ~~Extreme relative velocities of heavy particles in turbulent flow~~

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We present results from experiment and direct-numerical-simulation (DNS), on the statistics of relative velocity (δv) between small-heavy particles in the dissipative scales of turbulent flow. The experimental flow was nearly homogenous and isotropic at Taylor-scaled Reynolds number around 200. The particles were small liquid droplets ($d < 0.1\,\eta$) and have Stokes numbers (St) in the range of 0.04 to 0.51. The simulation was tuned to match the Reynolds, Stokes and Froude number of the experiments. Comparison showed that DNS reproduced all qualitative trends of the experiments. These included the stretched-exponential form of the tails of the distribution of δv, its skewness, its growth with Stokes number and particle separation. Good quantitative agreement were found for the negative δv (approaching particles) for sufficiently large St. We discuss the remaining quantitative discrepancies in terms of mismatch of intermittency between the experiment and DNS. We show that the tails of the distribution of δv are accounted for by the sling effect –a mechanism in which turbulent fluctuations causes the droplets to decouple from the background fluid and move toward each other with Stokes-dragged ballistic motions. We attempt to reproduce the forms of these tails and relate them to fluid flow statistics via the sling-start-scales –particle separations at the initiation of slings.

Damped wind-driven rogue waves

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Damping and wind effects play an important role in the stability and downshifting of waves. The physical and statistical properties of rogue waves in deep water are investigated using perturbed higher order nonlinear Schrödinger models. The effects of wind coupled with nonlinear damping on the development of rogue waves and the interaction between rogue waves and downshifting are examined using numerical investigations and analytical arguments based on the inverse spectral theory of the underlying integrable model, perturbation analysis, and statistical methods.

PT11: Plenary talk

Taming complexity: Controlling networks

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The ultimate proof of our understanding of biological or technological systems is reflected in our ability to control them. While control theory offers mathematical tools to steer engineered and natural systems towards a desired state, we lack a framework to control complex self-organized systems. Here we develop analytical tools to study the controllability of an arbitrary complex directed network, identifying the set of driver nodes whose time-dependent control can guide the system's entire dynamics. We apply these tools to several real networks, finding that the number of driver nodes is determined mainly by the network's degree distribution. We show that sparse inhomogeneous networks, which emerge in many real complex systems, are the most difficult to control, but dense and homogeneous networks can be controlled via a few driver nodes. Counterintuitively, we find that in both model and real systems the driver nodes tend to avoid the hubs. In collaboration with Y. Liu and JJ Slotine.

CT11: Networks II

Network vulnerability to extreme events

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Random walks on networks help us to understand various transport processes. We study extreme events on complex networks using the random walk model where the extreme events are defined as surpassing of the flux above a prescribed threshold. The study is motivated by the extreme events such as the traffic jams, floods, power black-outs that take place on networks. We had earlier found that the nodes with smaller number of links are more prone to extreme events than the ones with larger number of links [1, 2]. We obtain analytical estimates and verify them with numerical simulations. We also study extreme events for a biased random walk where the walks are preferentially biased towards either the hubs or the smaller degree nodes. Here, the probability of occurrence of an extreme event on any node depends on the 'strength' of the node, a measure of the ability of a node to attract walkers. The 'strength' is a function of the degree of the node and that of its neighbours. We find that the nodes with larger value of the strength, on an average, have lower probability for the occurrence of extreme events compared to the nodes with lower value of the strength.
Using the above notion of extreme events we study the nature of failure of a network by removing nodes which experience an extreme event and redistributing the walkers on the remaining or active nodes. Initially there is a slow decay of the number of active nodes. After about 15% to 20% of nodes are removed there is an almost sudden and sharp change in the behaviour and in a few time steps the entire network fails.

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The architecture of biologically inspired adaptive transport networks

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We investigate a class of adaptive transport networks, inspired by biological vascular systems (e.g. plant leafs, plasmodial veins of slime molds), modeled as undirected weighted graphs. The graphs edges represent tubes with Hagen-Poiseuille flow, connected through junctions, represented by their nodes. A local update rule, that changes the conductivity of the tubes (edge weights) according to the flow through them, is used as a self-organizing adaptation principle.
Varying the parameters of the system, we study the influence of the network's adaptation on its weighted topology. For this purpose, numerical simulations are done on common complex network topologies (e.g. Watts-Strogatz, Barabási-Albert, Erdös-Rényi) with random initial edge weights, and the complex statistical behavior of the adapting networks is measured with known metrics, that combine topological and weighted observables (e.g. strength distribution, betweenness centrality).

Analyzing the interplay among the layers of a multiplex on the overall diffusion dynamics

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Multiplex networks, i.e. networks consisting of interconnected layers, can model a variety of processes from natural or social sciences. For instance, they can model signaling channels, which in general participate in more than one type of interactions, thus performing more than one tasks in parallel [1]. They may also represent complex ecosystems, where the migration of different species occurs in different networks, or even social networks consisting of interconnected individuals from different relationship networks. In our study we focus linear processes on multiplex networks, whose dynamical properties are reflected to the spectral properties of the Laplacian matrix. Diffusion dynamics in two interconnected layers have been recently studied by Gomez et al. [2]. The construction of the so-called supra-Laplacian matrix was proposed as $\mathcal{L} = \mathcal{L}_0 + \mathcal{D}$, where $\mathcal{L}_0$ is a block diagonal matrix which corresponds to the Laplacians of each layer and $\mathcal{D}$ is the inter-layer adjacency matrix. Here, we generalize this study in multiplex networks consisting of more than two layers, which can be interconnected in various ways according to the matrix $\mathcal{D}$. It is also possible that, the intra-layer links have different weights than the links among the layers. We analyze the ratio of these two weights as well as the role of the inter-layer adjacency matrix on the spectral properties.

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Hierarchies behind failure of heterogeneous media

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The study of fracture of composite materials has a distinguished relevance due the broad and ever increasing use of multiphase materials to attend specific needs and/or combine cost and functionality. Theoretical approaches to the issue include simplified models, yet many times mathematically unfeasible, providing information of little practical use. As an alternate approach, lattice models for non-homogeneous media give the possibility of employing computer simulation to provide predictions or qualitative answers for the mechanical behaviour of composite materials.
The random fuse network has been one of the most successful lattice models in the last two or three decades [1, 2, 3, 4, 5, 6]. It places resistive fuses connecting nodes in a lattice, exploring the analogy between Ohm's law for conduction and Hooke's law for elasticity. As an external voltage drop, placed between two extremities of the network, increases, fuses will burn opening flaws in the lattice. It is the analogous to cracks growing and/or coalescing in a material as it is subject to tension, with the advantage of dealing with a scalar electrical problem, as opposed to the tensorial mechanical problem.
This model has been historically used with square, cubic or triangular lattices, but always regular lattices. Disorder, thought in a mesoscopic scale, was introduced by removing fuses *a priori* (dilution) or statistically giving the fuses different conductances or current thresholds.
This present work proposes that scale-free networks of fuses can describe the fracture process in composite materials without the use of *ad hoc* introduced disorder. This novel approach requires new ways of thinking the loading of a network based on its topology instead of its geometry, since node spatial localization has no clear meaning for this sort of network. Scale-free networks are characterized by the existence a highly connected node (hub) and a huge amount of poorly connected nodes, resulting in a power-law distribution of connectivities among nodes. Identified the roles of central (most connected) and peripheral (least connected) nodes, three load modes are proposed and tested, providing responses similar to classical cases of composite materials –fiber reinforced and highly porous.
Further analysis of the present model now unveils a correspondence between failure evolution profiles in heterogeneous materials and the fuse model in scale-free networks, with the hierarchy of load concentrators playing a major role. Simulations are also performed with other complex networks: apollonian networks (which are also scale-free) and random networks. Several conductance distributions were also tested, which revealed the distinction of universality classes defined only by the load mode and network type.

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Sisyphus effect in neural networks with spike timing dependent plasticity

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We study the collective dynamics of excitatory pulse coupled neural networks with spike timing dependent plasticity (STDP). In the absence of plasticity, the activity of the network exhibits only two stationary regimes: asynchronous or (partially) synchronous. The introduction of STDP leads to the emergence of endless irregular oscillations among completely synchronized and asynchronous states, resembling hippocampus activity during slow-wave sleep. This erratic population dynamics is driven by modifications in the synaptic weights induced by the level of synchrony in the network. This behavior can be explained by deriving a mean field equation for the evolution of the synaptic strength. This equation admits a stable fixed point, whose value depends on the degree of coherence among the neurons. In particular, synchronous (resp. asynchronous) firing forces the synaptic weights to evolve towards equilibrium values promoting the emergence of incoherence (resp. coherence) in the network. Therefore, STDP opposes to the relaxation of the system in a stationary macroscopic state inducing continuous oscillations between less and more synchronized states.

CT12: Dynamics of coupled oscillators

Phase dynamics of limit-cycle oscillators subjected to strong perturbations

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Synchronization of limit-cycle oscillators are ubiquitous in nature and has been studied over the years. To analyze the synchronization dynamics of limit-cycle oscillators, the phase-reduction method has proven to be a useful tool [1], but the conventional formulation is applicable only when the perturbation is sufficiently weak. In the present study, we propose a generalized phase-reduction method, which is applicable to strongly perturbed limit-cycle oscillators, if the perturbation can be decomposed into a slowly varying component and remaining fluctuation.
We consider a limit-cycle oscillator whose dynamics depends on a time-varying parameter $I(t) \in R^m$ representing general perturbations. It is described by

$$\dot{X}(t) = F(X(t), I(t)), \tag{1}$$

where $X \in R^n$ is a state variable representing the state of the oscillator and $F \in R^n$ is a vector field representing the oscillator dynamics. We assume that F has a family of stable limit-cycle solutions $X(t) = X_0(t, I)$ for each constant I in an open subset A of the parameter space and no bifurcation occurs within A. Unlike the conventional phase-reduction method, we define a generalized phase $\Theta(X, I)$ that is equivalent to the conventional phase at each constant I and smoothly depends on I. We further assume that the time-varying parameter $I(t)$ can be decomposed into a slowly varying component $q(\epsilon t)$ and the remaining weak fluctuation $\sigma p(t)$, i.e., $I(t) = q(\epsilon t) + \sigma p(t)$, where ϵ and σ are sufficiently small parameters. Under these assumptions, we introduce a phase variable $\theta(t) = \Theta(X(t), q(\epsilon t))$, whose evolution is described by

$$\dot{\theta} = \omega(q(\epsilon t)) + \sigma\zeta(\theta, q(\epsilon t)) \cdot p(t) + \epsilon\xi(\theta, q(\epsilon t)) \cdot \dot{q}(\epsilon t) + O(\sigma^2, \epsilon^2, \sigma\epsilon), \tag{2}$$

which is a generalized phase equation that we propose in the present study, where $\omega(I) \in R$ is a natural frequency of the oscillator at constant I, and $\zeta(\theta, I) \in R^m$ and $\xi(\theta, I) \in R^m$ are generalized phase sensitivity functions characterizing phase response of the oscillator to applied perturbations. Equation (2) is closed in θ and can be analyzed as easily as a conventional phase equation.
We will show that Eq. (2) can be used to analyze the dynamics of strongly perturbed oscillators, which cannot be analyzed by the conventional method. As an example, we analyze phase locking of limit-cycle oscillators to strong periodic forcing, whose orbit is largely deformed due to the forcing.

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Sequential switching activity in ensembles of excitatory and inhibitory coupled oscillators

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The heteroclinic cycles and channels are mathematical images of sequential switching activity in neural ensembles. Present a phenomenological model of such activity. The model is based on coupled Poincare systems. The existence of heteroclinic cycles and channels is shown.

Many dynamic processes in ensembles of coupled oscillatory systems demonstrate sequential switching activity between the individual elements and (or) groups of elements. Such sequential activity in neural network may be associated with different physiological functions of the nervous system [1]. Generation and distribution of sequences of excitation between the individual elements, as well as between groups of elements, play a critical role in functioning of the brain and the nervous system as a whole. For example, it is well known that such activity is an inherent property in sensory and motor neural systems of animals [2]. In addition, certain parts of a bird's brain generate sequences of burst activity. This sequences control the vocal apparatus and provide a song [3]. Other examples of the key roles played by the sequence of excitation in neural networks can be found in [4].

Sequential activity in oscillatory networks can be considered in terms of nonlinear dynamics. Thus, formation of a stable heteroclinic cycle in the phase space of corresponding dynamical system. This dynamical system simulates the activity of the network, can be the cause of such activity [5]. The basis principle of the generation of sequential switchings activity is the winnerless competition principle [6]. The essence of this principle is existence in the phase space of stable heteroclinic cycle between the trajectories of saddle type (saddle equilibrium points, saddle limit cycles) [7]. Passage of the phase point in the neighborhood of a certain saddle trajectory corresponds to activation of specific oscillators or groups of them. All such trajectories in the vicinity of heteroclinic cycle form heteroclinic channel. Thus, a stable heteroclinic channel in the phase space can be considered as a mathematical image of the sequential switching activity in ensembles of oscillators.

We study the question of the existence of a stable heteroclinic cycle between saddle limit cycles.

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Mean field and mean ensemble frequencies of a system of coupled oscillators

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Since the building units of the Kuramoto model [1] are defined by their natural frequencies, the macroscopic dynamics of any system consisting of interacting oscillators is also characterized by some average frequency. There are, however, two different quantities can be used for this: the effective frequency to which synchronized oscillators are locked, and the average frequency of all the oscillators, locked and unlocked, that belong to the observed system. The former represents the natural macroscopic frequency, whilst the latter is the microscopically averaged mean frequency. We shall call these respectively the mean field frequency and the mean ensemble frequency. [2]
Although there is no reason in general for these distinct frequency definitions to coincide, insufficient attention has been paid to formulating them for different parameters. Due to the equality of the frequencies in the symmetrical cases that were mostly studied, they were used interchangeably and without verification, even when they differed (e.g. see [3]). However, we wish to consider scenarios that most closely resemble actual physical or natural phenomena: in particular, models with asymmetrically distributed frequencies, phase-shifted coupling function, or asymmetric couplings of opposite sign. For these we show that the frequencies always differ and have non-trivial values. Moreover, whenever the population is experiencing a traveling wave state [3, 4, 5]), the locking of the oscillators occurs at a frequency different from the mean of the instantaneous frequencies.
Hence, one should be extremely cautious when the measured frequency of a population is interpreted and then compared with a theoretical model. Additionally, in inverse problems or in experiments it is often only the macroscopic parameters that can be obtained, meaning that a clear interpretation of the observed mean frequency is always needed.

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Complex dynamics and invariant tori in low-dimensional ensembles of oscillators.

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The case of two coupled oscillators is a classical [1]. But already the case of three coupled oscillators is complicated. Despite some features were known for a long time [2, 3], the general picture was formed not so long ago [4, 5, 6]. In the above references it was shows that the addition of each new oscillator significantly complicates the picture of the dynamical regimes and bifurcations. In present work we further increase the number of oscillators in the models and study ensembles of four or five elements. Here, we discuss the following fundamental questions.
How the results obtained for the phase model and for the original system of van der Pol oscillators correlate? What are the scenarios of birth of higher dimensional tori? What is the difference between the synchronization properties of the chain and network? How the possibility of in-phase or counter-phase synchronization of the pairs of elements demonstrates itself in the dynamics of ensemble? To answer these questions, we discuss and compare the scenarios and bifurcations for the phase model and a system of van der Pol oscillators. We are interested in embedding of the regions of regimes of different types in the parameter space of eigen-frequencies and coupling parameter. Phase model permits to illustrate a saddle-node bifurcation of tori of increasing dimension. For the original system there is a new opportunity - quasiperiodical Hopf bifurcation [7]. The increase in the number of oscillators allows to observe the resonance Arnold web based on the tori of different dimension. We show that under certain conditions the network of five oscillators allows to realize Landau-Hopf scenario, that is a possibility of the cascade (up to five steps here) of quasiperiodical Hopf bifurcations for the tori of higher and higher dimension. Comparison of the synchronization features for the chain and the network reveals a number of differences, in particular, in the organization of the region of the global synchronization, the number of the tongues of resonant tori, etc. The dynamics of networks is illustrated in the case of both in-phase and counter-phase synchronization of the pairs of elements. That is of interest to the problems in laser physics [8].
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Emerging of new classical structures in coupled chaotic microcavities

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Coupling of physical systems can make new classical structures which do not exist in a individual system. For example, the synchronization is most famous phenomenon in coupled nonlinear oscillators, which means that all variables of two systems become equal after transient time [1]. To achieve a synchronization, the synchronization manifold are needed, which emerges by the coupling of systems. In coupled microdisks, the attracting island structures which is called quasiattractor also appear due to coupling of two microdisks and the quasiattractors correspond to the intensity patterns of resonant modes [2, 3]. In this work, we report an abnormal high-Q modes in coupled chaotic microcavities, which are localized on new classical structure emerging from coupling.

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CT13: Nonlinear optics and lasers

Characterizing the dynamics of a semiconductor laser with optical feedback and modulation using ordinal analysis

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Semiconductor lasers subject to optical feedback and/or injection, are paradigmatic nonlinear systems, allowing experimental observation of a great variety of nonlinear behaviors. Here we focus on the complex dynamics arising due to the interplay of intrinsic laser nonlinearities, time-delayed feedback, and an external periodic forcing in the form of a direct modulation of the laser pump current.
For low to moderate feedback, and for pump currents close to solitary threshold, the laser presents sudden, irregular dropouts of its power output. This regime is referred to as low frequency fluctuations (LFFs). In the presence of a small modulation of the pump current, the LFF events tend to occur at the same phase in the drive cycle so that the inter dropout intervals (IDIs) become multiples of the modulation period. For increasing modulation amplitude the IDIs become progressively smaller multiples of the modulation period. Here, we use a method of time-series analysis that allows to infer the degree of stochasticity and determinism in the sequence of intensity dropouts. For each value of the modulation amplitude and frequency, the experimental sequence of IDIs is transformed into a sequence of ordinal patterns (OPs) of length D, by considering the relative length of D consecutive IDIs. This symbolic transformation keeps the information about the correlations in the dropout sequence and the short-time memory in the system, but neglects the information contained in the duration of the IDIs.
We compute the probabilities of the different words in the sequence, as well as the transition probabilities from one word to the next. We show that they vary with the modulation amplitude (or with the modulation frequency) and their variations allow identifying qualitative changes in the dynamics of the laser.

Distinguishing deterministic and noise-driven power-dropout events in semiconductor lasers with delayed feedback

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Semiconductor lasers with delayed feedback exhibit a variety of complex dynamical behaviours and thus serve as ideal testbeds for the study of delay-dynamics, chaos synchronization and its applications. The dynamics of semiconductor lasers subject to time-delayed feedback might be affected by an intricate interplay between deterministic mechanisms and intrinsic noise, the latter resulting from spontaneous emission and carrier fluctuations. Operating such a laser system close to its lasing threshold and at intermediate feedback strengths leads to a characteristic dynamical regime called Low Frequency Fluctuations (LFF). It is characterized and structured by irregular sudden power-dropouts, which designate the end of a dynamical cycle. The dropouts occur when the trajectory in phase space comes too close to an unstable antimode and is ejected towards the solitary laser mode [1].
There has been a lively discussion about how and when the LFF dynamics of a semiconductor laser in the chaotic regime is dominated by deterministic mechanisms or by stochastic processes [2], [3], [4], [5]. Numerical studies have shown that the qualitative features of the LFF regime in semiconductor lasers can be obtained without intrinsic noise. Nevertheless, noise could indeed affect the dynamics and induce dropout events, thereby shortening the LFF-cycle compared to a noiseless situation.
So far, most investigations to identify whether deterministic mechanisms or stochastic processes dominate the dropout behaviour have been based on statistical measures. In our contribution, we propose an event-based approach allowing to identify which power-dropouts in the LFF regime are deterministically induced by the feedback signal and not by noise. The approach we present is based on synchronization with a twin laser. Two semiconductor lasers with feedback that are coupled via a relay can exhibit identical synchronization of their outputs [6]. Their synchronization manifold is identical with the dynamics of an individual laser with feedback. We argue that if the lasers' intensities drop synchronously, the power-dropouts are induced by the deterministic mechanism of the feedback signal. If a dropout was noise-induced, the likelihood that this would happen simultaneously in both lasers is marginal.
Our analysis provides results for the ratio of dropouts induced by deterministic mechanisms. In particular we address the dependence of this ratio on the noise strength and on the lasers' pump current.
In experiments we have observed that two semiconductor lasers pumped close to threshold and coupled as described above, exhibit LFF-dropouts which occur synchronously about 80% of the time. This result is supported by numerical simulations based on a rate-equation model. The simulations show that the ratio of synchronous dropouts decays with increasing noise strength. Notably, this ratio is not much affected by the pump current, even for values close to threshold.
The method we present and the results provide insights into the effect of competing deterministic and stochastic processes in a delay dynamical system. In addition, they help to identify appropriate operational conditions for experimental applications based on chaos synchronization.

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Strong and weak chaos in networks of semiconductor lasers with time-delayed couplings

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We study the dynamics of semiconductor lasers both with time-delayed feedback and in small networks with time-delayed couplings. On the background of the theory of strong and weak chaos in delay systems [1], the dependencies of the maximum Lyapunov exponent on system parameters are considered analytically and demonstrated with simulations of the Lang-Kobayashi model. With increasing feedback strength the system exhibits the sequence weak-strong-weak chaos, where each regime is characterized by the typical scaling of the Lyapunov exponent with the delay time. The scaling at the transition between strong and weak chaos is discussed. An invariance of the dynamics for different pump currents is shown and related to a rescaling of the equations of motion. Further, we address the question, to which extent it is possible to distinguish between strong and weak chaos only by means of the laser trajectory. Correlation functions from an experimental setup of semiconductor lasers are compared to the numerical results, qualitatively indicating the different types of chaos. The analogy between weak chaos in a single feedback system and generalized synchronization in coupled systems is shown. We give an outlook on the general task of determining the underlying functional relationships by which these dynamical states are characterized.

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Experimental characterization of laser droplet generation dynamics

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Metal droplets have many potential applications in joining and 3D structuring. The laser droplet generation (LDG) is a novel process, which is used to generate a drop on demand from a metal wire. In the process a ring shaped laser beam is used as energy source for melting of the wire-end which is coaxially fed to the laser beam focus. From the molten wire-end a droplet under the action of the gravity and surface tension forces a pendant droplet is formed. The properties of the ring shaped laser beam focus enables detachment of pendant droplet on demand by Relay-Plateau instability of molten wire column which takes place above the neck of the pendant droplet due to the fast heating of this area by the laser beam. The main process parameters are laser power pulse, wire feeding parameters and position h_n of the laser beam focus with respect to initial position of the wire-end. For the purpose of process parameters optimization from the dynamic point of view, the influence of parameters on droplet dynamics should be known. In this paper the results of experimental characterization of the droplet formation and detachment dynamics with respect to the process parameters is presented. To describe the dynamics of LDG process, high speed IR camera images were used. From the IR images, the vertical and lateral oscillations of the droplet gravity point were extracted for quantitative characterization of the droplet dynamics. Additionally the process outcome was characterized by the diameter and surface temperature of pendant droplet. The temperature was measured by a 2-color pyrometer during droplet formation process. In the experiments the influence of the pulse power shape on the dynamics of pendant droplet formation process was investigated for several pendant droplet diameters. Formation of pendant droplet without and with the wire feeding during the laser pulse duration was considered. Results of pendant droplet formation experiments show that dynamics of pendant droplet depends on laser pulse power shape. The amplitude and decay time of the pendant droplet vertical and lateral oscillations during the formation process can be significantly decreased by using optimal (exponential power shape like) laser formation pulse and proper feeding of the wire. Low amplitude lateral oscillation of short duration assures that formed pendant droplet is coaxial to the wire-end what is important for the forthcoming successful detection. In addition to pendant droplet dynamic, the influence of the position of ring shaped laser focus with respect to the position of the pendant droplet neck h_n and the influence of droplet diameter on the dynamics of detached droplet was investigated. Successful detachment of pendant droplet of certain diameter takes place only in particular range of distances h_n between the neck of pendant droplet and the ring shaped laser beam focus spot. It has been observed that detached droplets can also have very different dynamics and trajectories with respect to h_n. In certain cases the droplet that is detached can be even reattached.

Chaotic canard explosions in a slow-fast nonlinear optomechanical oscillator

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In the last few years suspended-mirror resonators have become a research hot-topic, since they are ideal candidates for many quantum optics experiments [1]. In particular, the radiation-pressure coupling between the intracavity field and the mirror motion could enable the generation of nonclassical states of light, quantum nondemolition measurements of the field quadratures and eventually the creation entangled states of light and mirrors. However, even for light powers lower than those required for these experiments, the action of radiation pressure and photothermal effect (i.e. thermal expansion of the mirrors due to the absorbed intracavity light) becomes highly nonlinear. Since such processes are competing and are governed by very distinct time-scales, the dynamics of optomechanical resonators display special features, typically observed in high-dimensional slow-fast systems. Here we present an experimental study of these phenomena.

Typically, two-dimensional slow-fast systems undergo a supercritical Hopf bifurcation in which the attractor changes from a stable equilibrium to stable relaxation oscillations. The transition from the (Hopf) subthreshold oscillations to the relaxational regime, referred to as canard explosion [2], occurs within an exponentially small range of a control parameter, in which the system trajectories closely follow for some time also the repelling part of a slow manifold (equilibria of the fast sub-system).

Here instead, the initial Hopf bifurcation is followed by a period-doubling cascade and subsequent chaotic canard explosions, where large-amplitude relaxation spikes are separated by an irregular number of subthreshold oscillations [3]. The experimental results are reproduced and explained by means of a detailed physical model. We eventually show that these dynamics, as well as the structure and the stability of the slow-manifold, are fully compatible with those observed in a three-dimensional extension of FitzHugh-Nagumo model [4], where the motion on the fast manifold includes inertial terms, thus becoming, by necessity, two-dimensional [5].

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CT14: Spatio-temporal dynamics

Effects of nonlinear diffusion on biological population spatial patterns

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Anomalous diffusion is a realistic feature in the dynamics of many biological populations. Motivated by this observation, we investigate its implications in a paradigmatic model for the evolution of a single species density $u(x,t)$, the Fisher equation, which includes growth and competition in a logistic term and spreading through normal diffusion. Actually, we consider a generalization of Fisher equation with a nonlocal competition term, which has been shown to give rise to spatial patterns. We generalize the diffusion term through the nonlinear form $\partial_t u = D\partial_{xx}u^\nu$ (with $D,\nu > 0$), encompassing the cases where the state-dependent diffusion coefficient either increases $(v > 1)$ or decreases $(v < 1)$ with the density, yielding subdiffusion or superdiffusion, respectively. By means of numerical simulations and analytical considerations, we display and discuss how that nonlinearity alters the phase diagram.

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Spatial constraints in the distribution of linguistic diversity

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The distribution of human linguistic groups has many quantitative aspects parallel to the patterns exhibited by biological species. In particular, the area spanned geographically by a species and its population follow an allometric relationship. The same patterns have been observed for linguistic groups in the distribution of home ranges' areas and the number of speakers of each group. Moreover, the distribution of both area and population are well fitted by log-normal functions. The empirical evidence accumulated for the population-area relationship and the log-normal behavior of the distributions were recently used by Manrubia et al. [1] to develop a demographic dynamics that include conflicts over territory due to spatial growth. However, explicit spatial interactions between conflicting groups are not considered under this mean-field approach. In this contribution we couple the demographic growth with spatial restrictions through a network of neighboring groups. Our model predicts a long-tailed degree distribution in the network of spatial neighbors, and we find a very good agreement with empirical degree distributions. In addition, the correlation of area and population with degree, as well as the distribution of shortest-path lengths over the network, are correctly described by the model. Moreover, since our model networks are topologically different from classical families of networks, our results may have implications on the way in which human groups interact with each other.

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Spatial correlations in nonequilibrium reaction-diffusion problems by the Gillespie algorithm

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We present a numerical study of the spatial correlation functions of a one-dimensional reaction-diffusion system in both equilibrium and out of equilibrium. For the numerical simulations we have employed the Gillespie algorithm dividing the system in cells to treat diffusion as a chemical process between adjacent cells. We find that the spatial correlations are spatially short ranged in equilibrium but become long ranged in non-equilibrium. These results are in good agreement with theoretical predictions from fluctuating hydrodynamics for a one-dimensional system and periodic boundary conditions. Ultimately, the spatially long-ranged nature of correlations in nonequilibrium reaction-diffusion is the physical mechanism behind the appearance of Turing patterns.

On the stability of kink-like and soliton-like solutions of the generalized convection-reaction-diffusion equation

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We discuss the stability of traveling wave (TW) solutions of the following family of convection-reaction-diffusion equations:

$$\tau u_{tt} + u_t + g(u)u_x = [\kappa(u)u_x]_x + f(u). \tag{1}$$

Equation (1) can be formally introduced if one changes in the balance equation the convenient Fick's law $J(t,x) = -\nabla q(t,x)$, stating the generalized thermodynamical flow-force relations, with the Cattaneo's equation $\tau\frac{pJ(t,x)}{pt} + J(t,x) = -\nabla q(t,x)$, which takes into account the effects of memory.

Physically meaningful TW solutions to Eq. (1), such as periodic, kink-like and, soliton-like solutions, compactons, shock fronts, cuspons, and many other are either shown to exist or exactly constructed in papers [1, 2, 3, 4, 5, 6].

The aim of this report is to analyze the spectral stability of kink-like and soliton-like TW solutions of the equation (1). For the kink-like solutions the conditions assuring the spectral stability are given in explicit form. The soliton-like solutions supported by Eq. (1) seem to be unstable. For $g(u) = 0$ and $\kappa(u) = const$ it is the consequence of the Sturm oscillation theorem. In more general cases the situation is not clear enough, yet the numerical experiments performed with different $\kappa(u)$, $g(u)$ and $f(u)$, for which the source equation possesses the solitary-wave solutions of different types, reveal the instability in the wide range of the parameters' values.

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Selection of spiral waves in excitable media with a phase wave at the wave back

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A free-boundary approach is elaborated to derive universal relationships between the medium excitability and the parameters of a rigidly rotating spiral wave in excitable media, where the wave front is a trigger wave and the wave back is a phase wave. Two universal limits restricting the existence domain of spiral waves and a smooth transition between these two limits are demonstrated. The predictions of the free-boundary approach are in good quantitative agreement with the results from numerical reaction-diffusion simulations.

CT15: Biophysics and biomedicine

Biophysical origins of the second pitch-shift effects

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It has been known for a long time that the perceived pitch of a complex harmonic sound changes if the partials of the sound are shifted in frequency by a fixed amount. Based on simple nonlinear modeling, approximate rules for the shift of the pitch shift could be given (first pitch shift law). In psychoacoustic experiments, however, clear deviations from these predictions were observed (second pitch-shift effects). This raised the question of whether these deviations are due to the biophysics of the nonlinear hearing sensor, the cochlea, or an artifact generated higher up in the auditory pathway. In this article, we demonstrate that the second pitch-shift is generated in the cochlea, and that both combination-tone generation and low-pass filtering are the key factors responsible for the phenomenon. In particular, we find that the scaling laws of Hopf cochlea combination tones explain the classical, to date poorly explained psychoacoustical data of G.F. Smoorenburg (1970).

Evolutionary dynamics of populations with genotype-phenotype map

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There is a complex relationship between genotype and phenotype. One of the outstanding features of this map is that is not a one-to-one map, because many genotypes are compatible with the same phenotype. Whereas genes are the entities passed on from one generation to the next and their frequencies measured over populations (the remit of population genetics), selection acts at the level of phenotypes. Thus, assigning fitness values to genes (mutant variants, different alleles, etc.) is not, in general, the valid approach. We are trying to put forward some of new properties we may expect to emerge when the genotype- phenotype difference is taken into account, both in a general setting and in particular cases related to disease. We have been focused on formulating models of evolutionary dynamical processes with genotype-phenotype map, give a definition of phenotype based on the attractors of simple models of the dynamics gene regulatory networks, and simulate it in order to ascertain its dynamical properties. We have introduced a bipartite network to study genotype and phenotype together and their structural relationship. Also a way to understand their structure is to study their clustering coefficient, existence of communities, which are related to phenotypic robustness, or connectivity between communities (it means, innovation).

Heart rate variability analysis and its effectiveness in differentiate diseases

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The Heart Rate Variability (HRV) is quantified by the variation between RR intervals that depends on activity of the sympathetic and parasympathetic systems. Several classification methods have been proposed and used for a long time from different authors to analyze a RR time series from patients seeking to differentiate people with a specific disease from the health ones. However, so far it is not known how effective and general these methods are to classify a group that includes patients with several different diseases. The fundamental question here is whether there is any methodology that could be general and effective to be applied to any group of patients with several different diseases. In this work, based on an extensive comparative analyze we try to answer this question and provide a road map that can be used with efficiency in differentiate an ill person from a health one. We consider RR-interval time series from premature newborns, normal newborns, young adults healthy and adults with severe coronary artery disease and based on our analyze we were able to conceive a very effective methodology that allow us to properly differentiate a patient with several disease from a healthy person. This method is based on a supervised learning classifier that is known as Support Vector Machine.

Detecting nonlinear dynamics in human heart rate variability by deterministic nonlinear prediction

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Heart rate variability (HRV) is recognized as an important tool for assessing the state of the cardiovascular system and its dynamics. By itself, however, the mechanism of heart rate (HR) regulation is quite complex to study due to the variety of factors that contribute to it. In an attempt to improve understanding of HRV, recent studies have applied methods derived from nonlinear dynamics to such analyses. Nonlinear dynamics tools such as Lyapunov exponents and fractal dimensions have been commonly used for detecting deterministic chaos in HRV. These methods, however, are not sufficient to detect whether HR fluctuation is based on deterministic chaos or stochastic processes, whereas nonlinear prediction allows us to differentiate between random noise and deterministic chaos. In this study, heart rate data were measured from healthy males aged 25–30 years by a finger photoplethysmogram recorder (BACS Computer Convenience Inc., Japan). HR signals were recorded in a supine and sitting position for 1 min 40 sec with a sampling step of 0.005 sec. To detect nonlinear dynamics in HRV, coupled with correlation dimension and Lyapunov exponent calculations, a time delay embedding technique and deterministic nonlinear prediction method were applied to this time series. Nonlinear prediction was conducted for both single and several nearest neighbors. The correlation coefficient and relative root mean squared error between the predicted and real values were calculated. The resulting curve of correlation coefficient vs. prediction time step, which converged to zero, showed additional evidence of the presence of underlying nonlinear dynamics in HR fluctuations.

The interaction of disease spread and information propagation in metapopulation networks

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In the event of an outbreak, individuals are usually informed about the infection process by media, and these informed individuals, as information resources, often pass the information to other individuals. Intuitively, since individuals mobile spatially from one patch to another carrying the information to the whole network, the process of information propagation may help the informed individuals take a low risk of infection and thus reduce the prevalence as well. However, different mobility habits, induced by the behavioral response to the infection, may have different outcomes on the spreading process. Given the relevance for spreading process, here, we develop a theoretical framework that considers the interaction of the information propagation and the disease spread, aiming at understanding the impacts of mobility patterns of informed individuals (information propagation) on the disease spread.

The reaction and diffusion processes modeling the spread of an infectious disease and information propagation are considered as a two-step process. For the reaction process, since information propagation process is similar to the disease spreading process, we apply the basic SIS (susceptible-infected-susceptible) epidemic model to develop the analysis. Therefore, there are totally three states: susceptible (S), informed (A), and infected (I). The main difference from the SIS model is that each susceptible individuals may also be informed by contacting an informed individual with a fixed rate. Similar to the infected individuals, informed individuals may lost the information and turn to susceptible state again, or they get infected with a reduced transmission rate by contacting infected individuals.

Due to the mobility of individuals, the disease spreads to the whole network. The mobility may be just random by randomly moving to one of the neighboring patches, or individuals mobile depending on the behavioral responses such as safety-information-based mobility. By accounting for the behavioral response to the infection and through a metapopulation approach, we find that the mobility of informed individuals crucially affects the disease spreading process. The two invasion thresholds of the disease spread and the information propagation, R_0^d and R_0^a determine the existence of the disease or that of the information. Both theoretical analysis and numerical results show that the behavior affects the final prevalence as well as the invasion threshold.

CT16: Chaos

New theory of intermittency. Effect of noise on the length probability density

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Intermittency is a specific route to the deterministic chaos when spontaneous transitions between laminar and chaotic dynamics occur. The concept of intermittency has been introduced by Pomeau and Maneville in the context of the Lorenz system [1, 2]. Later it has been found that transition to chaos through intermittency occurs in periodically forced nonlinear oscillators, Rayleigh-Bénard convection, derivative nonlinear Schrödinger equation, turbulence evolution in hydrodynamics, and plasma physics. According to the type of instability in the laminar phase, the intermittency phenomena are usually classified in three classes called I, II, and III.
The main attribute of intermittency is a *global reinjection mechanism* that maps trajectories of the system from the chaotic region back into the *local* laminar phase. This mechanism can be described by the corresponding reinjection probability density (RPD). The RPD is a fundamental property of intermittency, determined by the chaotic dynamics of the system. Correct characterization of intermittency allows us to study problems with partially known governing equations in medicine and economics. Analytical expressions for the RPD are available for a few problems only. In the remaining cases the RPD must be obtained using experimental or numerical data.
Here we present a method to investigate the RPD in systems showing Type-I, II, or III intermittency. We generalize the classical analytical expressions for the RPD. This offers accurate description of the probability density of the laminar length and characteristic relation from experimental or numerical data [3, 4, 5, 6].
Noise may have strong impact on the intermittency phenomena. However, no work focused on the effect of noise on the RPD. Here we present an analytical approach to the noise reinjection probability density. To illustrate the method we use 1D maps and describe the general mechanism generating the RPD. We show that this mechanism is robust against the noise.
This work was supported by the former Spanish Ministry of Science and Innovation (FIS2010-20054), by the CONICET under Project PIP 11220090100809, and by grants of the National University of Córdoba and MCyT of Argentina.

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Universal scaling of Lyapunov-exponent fluctuations in space-time chaos

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Finite-time Lyapunov exponents of generic dynamical systems fluctuate in time. These chaotic fluctuations make the amplitudes of the Lyapunov vectors to wander around a pure exponential growth. A very recent numerical study [1] in several systems with space-time chaos has shown that these fluctuations obey a diffusive process in the long-time limit with a diffusion coefficient that scales with the system size with some wandering exponent γ. On the basis of numerical evidence it has been conjectured [1] that this exponent might be universal. Here we present a theoretical explanation of those numerical findings. We show that γ is indeed a critical exponent and can be linked to the scaling exponents of corresponding Lyapunov vector surface. We find that any Lyapunov exponent fluctuates with a wandering exponent $\gamma = 2\alpha - z$ in any space dimension, where z and α are the dynamic and roughenss exponent, respectively, of the Lyapunov vector surface. Moreover, for a wide family of systems the wandering exponent of the largest Lyapunov exponent can be analytically obtained from the critical exponents of the Kardar-Parisi-Zhang equation in any dimension and, therefore, we claim that the wandering exponent γ is universal. We compare our theoretical predictions with simulations of several models of space-time chaos. Our work shows profound connections between stochastic surface growth and the dynamics of Lyapunov vectors in spatio-temporal chaos, in particular it sheds some light into universal aspects of the scaling laws that gobern the thermodynamic limit of dynamical systems and chaos extensivity.

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From mode competition to polarization chaos in free-running VCSELs

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Vertical-cavity Surface-emitting lasers are known to suffer from polarization instabilities, but as semiconductor lasers it was believed they behave as damped nonlinear oscillators, only driven by two equations, and could therefore not produce a chaotic output without external perturbation or forcing. Here we demonstrate theoretically and experimentally that the additional degree of freedom offered by the surface emission and circular geometry of the device, which is responsible for the polarization instabilities, is sufficient to bring the laser into chaos [1].

The lack of polarization selectivity of VCSELs pave the way toward mode competition between the right and left circularly polarized emission, as described by the SanMiguel–Feng-Moloney (SFM) model [2]. Although lasing starts on a linearly polarized state at threshold, an increase of the injection current induces a pitchfork bifurcation that creates two symmetrical elliptically polarized solutions. A sequence of bifurcation occurs as the current is increased further hence creating two single-scroll chaotic attractors oscillating around the now unstable elliptically polarized steady-states. Behind a critical value of the injection current, the two attractors will merge into a double-scroll "butterfly" chaotic attractor [1].

Experimentally, this "butterfly" attractor is observed as a peculiar mode hopping between two elliptically polarized modes, i.e. polarization chaos, where we can easily observe and identify the jumps between the two wings of the "butterfly" attractor. As reported in Ref. [3], the average time between two successive jumps is exponentially reduced when the current is increased and ranges from seconds to nanoseconds time-scale. This evolution cannot be explained by the Kramer's escape theory as claimed for noise-induced mode hopping between two orthogonal and linear polarizations [4]. As we will detail, we unambiguously identify the chaotic behavior; in particular we compute the largest Lyapunov exponent and we apply the Grassberger-Procacia algorithm [5].

In this contribution, we prove that polarization chaos can be produced in free-running VCSELs, hence bringing new perspectives for simplifying conventional chaotic setups for applications like high-speed cryptography or random number generation. We also confirm the long standing prediction of the SFM model for VCSEL .

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Stability index for riddled basins of attraction

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We study a system with riddled basin of attraction whose basins are such that any point in the basin has pieces of another attractor basin arbitrarily nearby. In this paper, we consider a family of three-parameter maps of $\mathbb{R}^n$ to itself where this system exhibits riddled basin behaviour with that of the points at infinity. For these maps, we define the notion of stability index σ for this case of riddled basin and hence calculate the index as parameter ν is varied. Our results show that the proportion of the points in the basin that is in the δ-neighbourhood of A, $B_\delta(A)$ decreases with the increase of ν. Furthermore, we also obtained that different values of ν give different values of stability index with apparent monotonic decrease σ with ν where $\sigma = [-\infty, \infty]$. This stability index was first introduced by Podvigina and Ashwin [1] to quantify the local basin of attraction for the case of robust heteroclinic cycles.

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Universality in weak chaos

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We consider a general class of intermittent maps designed to be weakly chaotic, i.e., for which the separation of trajectories of nearby initial conditions is weaker than exponential. We show that all its spatio-temporal properties, hitherto regarded independently in the literature, can be represented by a single characteristic function ϕ. A universal criterion for the choice of ϕ to be fulfilled by weakly chaotic systems is obtained via the Feigenbaum's renormalization-group approach. We find a general expression for the dispersion rate of initially nearby trajectories and we show that the instability scenario for weakly chaotic systems is more general than that originally proposed by Gaspard and Wang [1].

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CT17: Stochastics processes

Stochastic crater at the nanoscale: experimental evidences

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Small systems such as cells, micelles and nanoparticles of catalyst can witness various non-equilibrium reactions. Probing the reactions and their dynamics at this scale represents a real challenge, because of the scarcity of high-resolution techniques. Real-time FEM (Field Emission Microscopy) is a powerful method for studying the dynamics of catalytic reactions that take place at the surface of a nanosized metal tip, which acts as a catalyst. FEM is based on the emission of electrons from the sample which can be affected by the presence of various adsorbates. Local variations of the work function are reflected in the form of a brightness pattern. The microscope is run as an open reactor through a constant supply of gaseous reactants and constant gas-phase pumping of the reaction chamber, ensuring that the system is kept far from thermodynamic equilibrium. The study of those non-linear dynamics at the nanoscale is achieved by a careful analysis of the brightness signal. We show how the dynamical attractors and the phase space dynamics of such reactive systems can be reconstructed from experimental time series. In the present case, NO2 hydrogenation over Pt nanosized tips is investigated. For specific values of the control parameters, the presence of robust chemical clocks is highlighted. These periodic self-sustained oscillations can be linked to a limit cycle which, because of the spontaneous fluctuations induced by the system's small size, actually defines a "stochastic crater" on the slopes of which dynamical trajectories can develop. This structure persists even for very small systems, i.e. for local areas as small as 7 nm^2.

A binomial stochastic simulated study of mutualism

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Mutualism is the interaction between two species that results advantageous for both. Mutualistic communities have an internal structure of bipartite network [1], with a property called *nestedness* that makes them quite resilient [2]. Research has focused on stability to explain the reasons of this effect [3] but dynamics is less well understood. Theoretical models are modifications of the classical logistic equation with additional terms to take into account interspecies interactions [4], but they are not fully satisfactory for simulation under all circumstances. We have developed a model of mutualism based on the aggregation of benefit for each species in its equivalent growth rate:

$$\begin{aligned} \frac{dN_j^a}{dt} &= r_{eq_j}^a(r_{b_j}^a, r_{d_j}^a, N_0^p, N_1^p, ..., N_m^p)N_j^a - |r_{eq_j}^a(r_{b_j}^a, r_{d_j}^a, N_0^p, N_1^p, ..., N_m^p)|\frac{N_j^{a\,2}}{K_j^a} \\ \frac{dN_l^p}{dt} &= r_{eq_l}^p(r_{b_l}^p, r_{d_l}^p, N_0^a, N_1^a, ..., N_n^a)N_l^p - |r_{eq_l}^p(r_{b_l}^p, r_{d_l}^p, N_0^a, N_1^a, ..., N_n^a)|\frac{N_l^{p\,2}}{K_l^p} \end{aligned} \tag{1}$$

Where the superscripts stands for each of both class of species, in a system with n of class *a* and m of class *p*. Each equivalent rate is a function of natural birth and death rates of the species and of the populations of the mutualistic class. With these equations, we have built a binomial stochastic simulator for the study of system dynamics [5]. It allows the introduction of external perturbations such as step increases in mortality by plagues, removal of links between species due to evolution, or overlapping of a predator foodweb. With this toolbox, we have simulated different scenarios that explain, for instance, why newcomer species have more chances of survival if they link to the generalist nested core, and how extinctions can spread and lead to a total collapse with a minimum change in the intensity of the external perturbation.

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Patterns and survival of competitive Levy and Brownian walkers

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Competition for common resources is one of the fundamental interactions among biological organisms. The spatial distribution of individuals greatly modulates interaction strength, and it is itself affected by the organism's type of motion. Here we study the population dynamics of individuals undergoing birth and death and diffusing by Gaussian jumps or by Levy flights. We establish the conditions for which competitive interactions induce clustering and periodic patterns, and show how the type of motion may confer competitive advantage [1, 2, 3].

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Noise assisted morphing of memory and logic function

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A large body of research has focused on the cooperative interplay of noise and nonlinearity in dynamical systems, leading to phenomena such as stochastic resonance. In this direction, Murali et al [1] investigated the response of a bistable system to an external signal, encoding logic inputs. It was demonstrated that in an optimal band of noise, the output of the system, determined by its state, was a consistent logical combination of the inputs.

This phenomenon has been termed logical stochastic resonance (LSR), and it suggests a new way of implementing reconfigurable and reliable logic gates in the presence of noise. The main feature of LSR is the capability of the nonlinear device to work optimally in a range of environmental noise; hence LSR is a practical and reasonable answer for computational devices wherein the noise-floor cannot be suppressed.

We extend the concept of LSR and demonstrate how noise allows a bistable system to behave as a memory device also [2]. Namely, in some optimal range of noise, the system can operate flexibly, both as a NAND/AND gate and a Set–Reset latch, by varying an asymmetrizing bias. Thus we show how this system implements memory, even for sub-threshold input signals, using noise constructively to store information. This can lead to the development of reconfigurable devices, that can switch efficiently between memory tasks and logic operations. Further, we examine the intriguing possibility of obtaining dynamical behavior equivalent to LSR in a noise-free bistable system, subjected only to periodic forcing, such as sinusoidal driving or rectangular pulse trains. We find that such a system, despite having no stochastic influence, also yields phenomena analogous to LSR, in an appropriate window of frequency and amplitude of the periodic forcing [3]. Next, we show that it is possible to obtain a logic response similar to LSR even when the strength of noise is lower then the minimum threshold. This enables us to use the LSR elements in subthreshold noise conditions. Further, by coupling the LSR element to another LSR element with a lower potential barrier we can make the systems to adapt to varying noise intensity so that its operation is robust even in high noise conditions [4]. We also demonstrate the realization of logic operations and memory with engineered genetic networks. We investigate the effects of the interplay of noise, nonlinearity and time delay on the operational range of this biological logic gate. We also demonstrate that the desired “logical” response to inputs can be induced, even in the absence of noise, by time delay alone [5].

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Effects of noise on the Shapiro steps

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Effects of noise on the existence and properties of the Shapiro steps have been studied in the ac driven overdamped Frenkel-Kontorova model with deformable substrate potential. The results have shown that the influence of noise on interference phenomena is determined by the presence and the size of halfinteger steps. Since halfinteger steps are more affected by noise, and the properties of harmonic steps are directly correlated with the size of halfinteger steps, noise will have completely different effects on the harmonic steps if halfinteger steps are present. As temperature increases, in the amplitude dependence of the step width, deviation from the well-known Bessel-like oscillations has been observed, and three different types of behavior have been classified. In the influence of noise on the frequency dependence of the steps, appearance of oscillations and strong influence of halfinteger steps on their form have been observed.

CT18: Biological and ecological systems

Micro and macro-scale models of population dynamics in a cell culture

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Population dynamics in a cell culture has practical importance in many fields like biology, medicine and biomedical engineering. In this study two different deterministic models at two different scales are proposed for population dynamics in a eukaryotic cell culture. Although based on the same fundamental biological knowledge on the reproduction dynamics of eukaryotic cells, these models differ in terms of their assumptions and resolution. The micro-scale model is a simplified deterministic simulation of the cells' reproduction dynamics in the form of a multi-agent system, while the macro-scale model represents the population dynamics as a flow in a phase space spanned by 4 global state variables, where only one variable can be experimentally measured. The validity of the macro-scale model is limited by certain homogeneity conditions. It is rather realistic to assume that the systems starts with a relatively homogeneous initial condition. For the viability of the macro-scale model, however, it must be demonstrated that the dynamics under consideration does not amplify small heterogeneities. In this contribution simulation results of the micro-scale model will be used as a basis of comparison for the evaluation of the macro-scale model. Furthermore, based on this specific modelling example some general conclusions will be drawn about "macro-modellability".

Complex communication between social whales

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Complex vocal communication simultaneously requires high cognitive abilities, a large flexibility in sound production, and advanced social interactions. Among non-humans, social whales are closest to fulfill these requirements. The fundamentals about how acoustic signals are used and how acoustic patterns are organized, however, are largely unknown. Up to date, mostly human observers classify acoustic patterns through hearing and visual comparison of spectrograms, making any such classification partly unreliable and highly subjective. Thus, objectively relating specific acoustic patterns to an observed context seems impossible so far. Here, we propose a novel perspective and study distributions of acoustic features (in particular, cepstrum coefficients) generated from ensembles of killer whale vocalizations conditioned on contexts. Comparing these distributions by computing Kullback-Leibler-divergences we find substantially different distributions for specific behavioural contexts, such as salmon feeding, herringfeeding or non-feeding.

A functional network representation of the DNA

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Escherichia coli is a bacteria that is present in human digestive system and is one of the commonly used model organisms: its DNA is well known, well studied, and can be used to test mathematical approaches towards modelling the DNA. In this work, we design a special encoding to represent nucleotide sequences into symbolic sequences and create a symbolic map of the E.coli DNA. This map allows for a straightforward characterisation of the DNA generating it through informational (Shannon's source entropy and mutual information rate) and metric measures (Lyapunov exponents) [1]. We also establish functional connectivity between two regions in this symbolic map (representing two groups of similar nucleotides, i.e. two words) based on the rate at which information is exchanged and on the decay of cross correlation. Interpreting a node to represent a groups of similar words (a region in the symbolic space) and edges to represent the functional connections between them (measured by the rate of information exchanged or the coefficient of the correlation decay) allows us to construct a network representation of this DNA, a graph representation of the grammatical rules governing the appearance of nucleotide words.

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Physical properties of the phloem constrain size and shape of leaves

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We model the leaf phloem vascular system of plants as a complex weighted web of producer nodes (where sugar production happens) connected to a collector node (the petiole or leaf stalk). In plants, such vascular systems are thought to be optimized over the course of evolution for their designated function. Under the assumption of optimal nutrient uptake but finite resources for the production of veins (network edges), we examine the resulting network properties. We find that for a certain parameter range, only a subset of the available producer nodes is used, leading to constraints for shape and size of leaves.

Spatio-temporal dynamics of ecosystems for acorn masting and ecological management

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Masting is a well-marked yield variability phenomenon in oak forest production. In Japan, this phenomenon is also related to wild animal management (e.g. of animal such as wild boars, that rely on acorn as their major feed source). In this study, the capability of integrating remote sensing technology into ecological process analysis was demonstrated, whereby spatial variation of acorn production was investigated over large spatial ranges across three years (2008-2010). In addition, methods of Moran's I and kriging interpolation were also adopted in our research for acorn assessment to compare with remote sensing based approach. After validation, remote sensing was chosen for mapping acorn harvest by using ENVI and GIS. After that, GPS data which can reveal wild animal behaviors were obtained in our research. Programming for analysis wild animals' social phenomenon and dynamically changing was conducted by using multi-agent simulator Artisoc software (KOZO KEIKAKU ENGINEERING INC., Japan). According that, the relationship between wild animal behaviors and acorn harvest was analyzed.

CT19: Statistical physics

Criticality in dynamic arrest: Correspondence between glasses and traffic

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Dynamic arrest is a general phenomenon across a wide range of dynamic systems including glasses, traffic flow, and dynamics in cells, but the universality of dynamic arrest phenomena remains unclear. We connect the emergence of traffic jams in a simple traffic flow model directly to the dynamic slowing down in kinetically constrained models for glasses. In kinetically constrained models, the formation of glass becomes a true (singular) phase transition in the limit $T \to 0$. Similarly, using the Nagel-Schreckenberg model to simulate traffic flow, we show that the emergence of jammed traffic acquires the signature of a sharp transition in the deterministic limit $p \to 1$, corresponding to overcautious driving. We identify a true dynamic critical point marking the onset of coexistence between free flowing and jammed traffic, and demonstrate its analogy to the kinetically constrained glass models. We find diverging correlations analogous to those at a critical point of thermodynamic phase transitions.

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Complex Systems with an H-Theorem

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In this communication, some complex systems showing a near trivial dynamics are addressed, namely a completely random market and a gas of free particles. First, the asymptotic statistical equilibria for these systems are found by straightforward geometrical arguments, which are a consequence of the hypothesis of equiprobability. Second, two new models are proposed to explain the decay of these statistical systems from a general out-of-equilibrium situation toward their equilibrium states. Third, the existence of an H-theorem for both systems can be checked by computational essays. Finally, some results on the implementation of this type of models on networks are presented.

Nonequilibrium phase transitions caused by dynamical traps

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The concept of dynamical traps was introduced to describe the bounded capacity of human cognition in evaluating events, actions, etc. according to their preference [1]. Humans just are not able to distinguish between two strategies of behaviour similar in properties. So when the dynamics of a system governed by an individual (operator) deviates from the optimal conditions not too substantially the operator sees no reason to correct it. Therefore the active behaviour of the operator is stagnated until the system deviates substantial form the optimal conditions. Then, naturally, the operator corrects the system motion returning it to some proximity of the optimal motion.
The particular goal of the present work is to demonstrate that the dynamical traps can be responsible for complex emergent phenomena in such systems. To be specific the cooperative phenomena in the chain of oscillators with dynamical traps called the lazy bead model is discussed in detail. It generalizes the model studied previously [2], in particular, considers the fuzzy actions of the operator not only with respect to the system state but also his behaviour strategy. In the given system various phase transitions different in properties are found numerically. It is shown that such systems admit a new mechanism of instability not related to the change in the form of regular “forces” as is the case in the classical theory of phase transitions in physical media.
The results are discussed in the context of several examples; they are:
(*i*) A dynamical system with partial equilibrium. These systems imitate, for example, car following and the corresponding model of dynamical traps is a natural generalization of the notion of stationary point. In this case the domain of dynamical traps can be treated as a low dimensional region in the corresponding phase space such that the motion of the system is stagnated when it enters this region.
(*ii*) An unstable system whose stability is due to human control. As a characteristic example, balancing a virtual over-damped pendulum is discussed.
(*iii*) A model taking into account the bounded capacity of human cognition in choosing the appropriate actions to correct the current state of a controlled system. It is demonstrated that due to the effect at hand the corresponding governing equations no longer obey to the paradigms of Newtonian mechanics. For example, such a system can be described by an extended phase space containing also a particle acceleration as an individual phase variable.
Keywords: Social systems, Human behavior, Bounded capacity of human cognition, Fuzzy rationality, Dynamical traps, Emergent phenomena, Phase transitions.

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The mechanics of structured particles and why it is important

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Necessity of creating of the mechanics of structured particles (SP) is discussed. Here the SP is equilibrium system consisting from a large number of potentially interacting material points (MP) [1, 2, 3]. The main argument in favor to create a mechanical SP is the fact that all natural objects are the systems and all processes in nature are evolving and irreversible [4]. But from the formalism of classical mechanics follows that the dynamics of systems is reversible. Reversibility follows from Newton's motion equation for MP, potentiality of the collective forces that determine the motion of the systems. All attempts to solve the problem of irreversibility i.e. describe the processes of evolution in the framework of Hamiltonian formalism, beginning from Boltzmann and until recent years, did not give the desired result.
The most generally accepted explanation of the mechanism of irreversibility is based on the property of exponential instability of Hamiltonian systems and the existence of arbitrarily small fluctuations. The essence of the explanation is the following. The Poincare theorem about reversibility of the Hamiltonian systems tell us that there is although a very large but finite time, during which the system will be arbitrarily close will come near by the starting point of the phase space. Then if we average over the small neighborhood of point of the phase space where a system is, it will not return to its original state due to of the exponential instability. Such averaging is equivalent to the arbitrarily small fluctuations in the system. I.e. the presence of fluctuations in Hamiltonian systems provides them irreversibility. But the using of fluctuations in the explanation of the irreversibility is alien to the classical mechanics. Furthermore, they impose limits on the depth and the horizon of knowledge of the world.
However, it turns out that we can come to an explanation of irreversibility in the framework of the laws of Newtonian mechanics without any probabilistic hypotheses about of the fluctuations. For this purpose we must do the following: to replaced the MP on the SP; to submit SP energy as the sum of its motion energy and internal energy; to obtain the SP motion equation from this energy.
Here we will show: how to obtain SP motion equation; how the concept of entropy may be included into the mechanics; why the mechanics of SP can be regarded as a "bridge" that links Newtonian mechanics with thermodynamics, statistical physics and kinetics. And this, in turn, is a prerequisite to the creation of the basic physics of evolution which is necessary for construction the modern picture of the world.

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A tower of scales in plasma modeling: Order, disorder, fusion

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A fast and efficient numerical-analytical approach is proposed for the description of complex behaviour in non-equilibrium ensembles both in the BBGKY framework and in a number of its Vlasov-Poisson/Maxwell reductions. We construct a multiscale representation for the hierarchy of partition functions by means of the variational approach and multiresolution decomposition. Numerical modeling shows the creation of various internal structures from fundamental localized (eigen)modes. These patterns determine the behaviour of plasma. The Waveleton, localized (meta) stable long-living pattern with minimal entropy and zero measure, is proposed as a possible model for the energy confinement state (the fusion state) in plasma.

CT20: Fluid dynamics

CANCELLED. ~~Extreme events in turbulent relative dispersion~~

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The long-term diffusive behavior of tracers in a turbulent flow is often used to model transport. Effective mixing properties are modelled in terms of an eddy diffusivity, which is used to assess possible health hazards due to a long exposure downstream a pollutant source. However this approach fails when interested in the likeliness of finding local concentrations exceeding a high threshold. Such fluctuations cannot be determined from the average concentration as they relate to higher-order moments. Second-order statistics, such as the spatial correlations of a passive scalar, are related to the relative motion of tracers. In most applications, such as meteorology, mechanical engineering and biology, this dynamics is usually approximated by Richardson's diffusion model.
We study the statistical properties of the relative dispersion of tracer pairs in a homogeneous isotropic turbulent flow. For this we make use of direct numerical simulations of the Navier–Stokes equation using 4096^3 grid points to attain a Reynolds number $R_\lambda \approx 730$. A particular attention is given to the large fluctuations encountered by tracers. We observe that the distribution of distances reaches a quasi self-similar regime, which is characterized by a very weak intermittency. The timescale of convergence to this behavior is given by the kinetic energy dissipation time at the spatial scale given by the initial separation between tracers.
Conversely, the velocity differences between tracers show a strongly anomalous behavior whose scaling properties are close to those of the Lagrangian structure functions. Such violent fluctuations are interpreted geometrically and we show that they are responsible for a long-term memory of the initial velocity. Despite this strong intermittency, the average local rate of energy transfer, defined as the ratio between the cube of the longitudinal velocity difference and the distance between tracers, reaches a statistical steady state on short time scales.
Finally these results are put together to attack the question of violent events in the distribution of distances. We find that the largest separations are reached by tracer pairs that have always separated very fast since the initial time. They are responsible for the presence of a stretched exponential tail in the probability distribution. At long times, this tail becomes closer to an exponential than to the distribution predicted from Richardson's approach. At the same time, the distribution of distances develop an algebraic behavior at small values that we interpret in terms of fractal geometry. Numerical data suggest that this exponent converges to one, which is again in conflict with Richardson's prediction. These two asymptotic results show that turbulence is mixing in a much less efficient manner than what is expected in currently used models.
The research leading to these results has received funding from the European Research Council under the European Community's Seventh Framework Program (FP7/2007-2013, Grant Agreement no. 240579).

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Numerical simulation of hypersonic real gas flow

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The development of prospective airspace vehicles required conduction of various complex numerical and experimental investigations closer to real flight conditions. The classification of gases (Anderson J.D.) divides perfect gas onto three groups according to the effects occurring on it. Vibrational degrees of freedom are frozen at low temperature and translational and rotational degrees of freedom are in equilibrium. In this case, the specific heat of the gas is constant c_p=const and such gas called calorically perfect. Temperature increasing is resulting to excitation of the vibrational degrees of freedom of the gas molecules. The specific heat of such thermally perfect gas is not constant and depending on temperature $c_p = f(T)$. These high temperature effects (real gas effects) have essential influence on the mean flow around an aircraft and on its shock layer receptivity.

The present work deals with numerical simulation of the influence of internal degrees of freedom on the mean flow and development of disturbances in the hypersonic shock layer over a flat plate with sharp leading edge. Numerical simulation was performed using the ANSYS Fluent package. Simultaneously, the investigation of flow over a plate $L = 0.2$ m ($Re_L \sim 7 \times 10^5$) at angle of attack α=10.2° in hypersonic ($M_\infty > 6$) flow of air, carbon dioxide and mixture of carbon dioxide and air, at high stagnation temperature (under 3000 K) were conducted in the high enthalpy aerodynamic wind tunnel IT-302 ITAM SB RAS. The Schlieren method was used to visualize of mean flow. The problem of hypersonic flow over plate at angle of attack was solved in two stages. In the beginning, the numerical simulation of flow in the prechamber and nozzle of wind tunnel IT-302M was performed and the flow parameters on the nozzle outlet (i.e. in the test section) were obtained. Numerical simulation was performed by solving the two-dimensional Navier-Stokes equations with addition of $k - \omega$ SST turbulence model. The computational domains were constructed based on the drawing of real shaped nozzles. Then using obtained data, the problem of flow over the plate at angle of attack in the test section of the wind tunnel and receptivity of viscous shock layer to external slow acoustic disturbances with account for exciting of internal degrees of freedom of carbon dioxide molecules was solved. The flow over the plate of calorically perfect gas, thermally perfect gas and flow with parameters of the real gas model from NIST database was considered. The comparison of the shock layer characteristics shows the excitation of vibrational degrees of freedom of carbon dioxide molecules essentially changes the shock wave position.

The investigation of viscous shock layer receptivity showed that amplitude of pressure fluctuation on the plate surface for CO_2 essentially greater than for air and mixture of air and CO_2. The phase shift was observed between variations of rms pressure pulsations for CO_2 and air, which indicates the complex effect of sound speed, boundary layer thickness and temperature in shock layer. These parameters depend on excitation of vibrational degree of freedom.

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Hydrodynamic instability in two orbiting particles levitated in a vibrated liquid

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Archimedes principle does not apply in the absence of gravity; in space, any collection of particles can form a suspension in a liquid, regardless of their mass or density. If such a suspension is vibrated, the particles and the fluid will move relative to each other if their densities are different. The resulting hydrodynamic flows in the liquid can strongly influence the behaviour of the suspended particles. We refer to such a collection of particles in a fluid as a density-mismatched suspension. We show how diamagnetic levitation can be used to study a density-mismatched suspension, effectively reproducing the effect of weightless conditions in an orbiting spacecraft. We have studied the behaviour of two spheres suspended in a liquid of lower density than the spheres, which is vibrated to induce hydrodynamic flows around the spheres. Under vibration the spheres attract and for sufficiently large vibration amplitudes the spheres are observed to spontaneously orbit each other. Measurements of the orbital angular velocity of the spheres versus vibration amplitude, frequency, liquid viscosity and sphere diameter show that the instability occurs at a critical value of the streaming Reynolds number. We present video images of the flow surrounding the spheres, and the results of simulations, which reveal the cause of this novel instability.

Limit cycle behavior in the statistical description of turbulent Rayleigh-Bénard convection

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Rayleigh-Bénard convection describes the buoyancy-induced movement of a fluid that is enclosed between two horizontal plates. It serves as a idealized setup of phenomena occurring in nature and technical applications, and is a paradigm for studies of stability theory and dynamical systems. The temperature fluctuations that occur in the fully turbulent case are of special interest, yet they can't be directly described from first principles due to the chaoticity of the system. Therefore we describe the statistics of temperature fluctuations by investigating the probability density function (PDF) of temperature. Our ansatz is to derive exact evolution equations that describe the shape and deformation of the PDF; unclosed terms appearing in the form of conditional averages are estimated from direct numerical simulations of turbulent Rayleigh-Bénard convection in a cylinder. Following these steps, a limit cycle behaviour appears in the phase space of the temperature PDF, highlighting the connection between the statistics and the dynamics of the system that our ansatz permits. The properties, interpretations and implications of this limit cycle are discussed; also, it is shown that the limit cycle can be connected to coherent structures formed by the convecting fluid.

Numerical study for convection near the stability threshold in a finite homogeneously heated fluid layer.

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The paper presents numerical study of convection in a finite homogeneously heated fluid layer. Main properties of roll and hexagon flow structures are investigated for Prandtl number in the range $[0.1, 100]$ and Rayleigh number from subcritical values up to $10Ra_{cr}$. The effect of Prandtl number and heat strength on the extent of stable hexagons region is determined. For the first time different direction of circulation in the stable hexagons at Prandtl number below a certain critical value Pr_{cr} and above it is revealed in calculations. Close to Pr_{cr} stable overcritical roll convection has been registered.

PT12: Plenary talk

Meso-scale structures induce characteristic instabilities in networks of coupled dynamical systems

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The dynamics of networks of interacting systems depend intricately on the interaction topology. Dynamical implications of local topological properties such as the node degrees and global topological properties such as the degree distribution have intensively been studied. Meso-scale properties, by contrast, have only recently come into sharp focus of network science but developed rapidly into one of the hot topics in the field. Current questions are: Can considering a meso-scale structure such as a single subgraph already allow conclusions on dynamical properties of the network as a whole? Can we extract implications that are independent of the embedding network? And, which meso-scale structures should be considered? Here, we show that certain meso-scale subgraphs have precise and distinct consequences for the system-level dynamics. In particular, they induce characteristic dynamical instabilities that are independent of the structure of the embedding network.

PT13: Plenary talk

Time as coding space for information processing in the cerebral cortex

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Higher cognitive functions require the coordination of large assemblies of spatially distributed neurons in ever changing constellations. It is proposed that this coordination is achieved through dynamic coordination of temporally structured activity. Since there is no supra-ordinate command centre in the brain, the respective patterns of coherent activity need to self-organize within the fixed architecture of anatomical connections. Evidence will be provided that dynamic coordination supports response selection by attention, subsystem integration, flexible routing of signals across cortical networks and access to the work-space of consciousness. The precision of temporal coordination is in the millisecond range suggesting the possibility that information is encoded not only in the co-variation of discharge rates but also in the phase relations of discharges relative to population oscillations. This phase coding could account for the high speed with which cortical circuits can encode and process information. Recent studies in schizophrenic patients indicate that this disorder is associated with abnormal synchronisation of oscillatory activity in the high frequency range (beta and gamma). This suggests that some of the cognitive deficits characteristic for this disease result from deficient binding and subsystem integration.

MS26: Complex networks in climate dynamics

Network of networks and the climate system

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Network of networks is a new direction in complex systems science. One can find such networks in various fields, such as infrastructure (power grids etc.), human brain or Earth system. Basic properties and new characteristics, such as cross-degree, or cross-betweenness will be discussed. This allows us to quantify the structural role of single vertices or whole sub-networks with respect to the interaction of a pair of subnetworks on local, mesoscopic, and global topological scales. Next, we consider 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 technique is then applied to 3-dimensional data of the climate system. We interpret different heights in the atmosphere as different networks and the whole as a network of networks. This approach enables us to uncover relations to global circulation patterns in oceans and atmosphere. The global scale view on climate networks offers promising new perspectives for detecting dynamical structures based on nonlinear physical processes in the climate system. This concept is applied to Indian Monsoon data in order to characterize the regional occurrence of strong rain events and its impact on predictability.

Interaction network based early warning indicators for the Atlantic MOC collapse

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Early warning indicators of the collapse of the Atlantic Meridional Overturning Circulation (MOC) have up to now mostly been based on temporal correlations in single time series. Here, we propose new indicators based on spatial correlations in the time series of the Atlantic temperature field. To demonstrate the performance of these indicators, we use a meridional-depth model of the MOC for which the critical conditions for collapse can be explicitly computed. An interaction network approach is used to monitor changes in spatial correlations in the model temperature time series as the critical transition is approached. The new early warning indicators are based on changes in topological properties of the network, in particular changes in the distribution functions of the degree and the clustering coefficient.

Coupling within and across multiple scales of climate dynamics

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Complex networks as a new paradigm for understanding emergent phenomena in complex systems have recently been introduced into climate science and analyses of climate-related data. A multivariate time series of measurements of a meteorological variable, such as air temperature or pressure, is converted into a (weighted) graph by quantification of pair-wise dependence between time series representing dynamical evolution of the variable recorded in two nodes of a climate network. Then the graph theory is used to identify important features of the network such as scale-free or small-world topology, highly connected hubs and modularity, and helps to understand information or mass transfers among subsystems or modules of the network. Typically, the network links are assessed as cross-correlations between deseasonalized total variability of a variable of interest [1]. However, the complex dynamics of the Earth atmosphere and climate evolve on a wide range of temporal and spatial scales. Analyses of the low-frequency variability on seasonal to decadal time scales have led to detection of oscillatory phenomena possibly possessing a nonlinear origin and exhibiting phase synchronization between oscillatory modes extracted either from different types of climate-related data or data recorded at different locations on the Earth [2, 3, 4]. Evaluation of scale- or frequency-specific connectivity leads to climate networks of different topological properties, accenting different climate phenomena acting on different time scales. We can also study nonlinear interactions between dynamics on different temporal scales: In about a century long records of daily mean surface air temperature from various European locations, using conditional mutual information together with the Fourier-transform and multifractal surrogate data methods [5], we can observe information transfer from larger to smaller scales as the influence of the phase of slow oscillatory phenomena with periods around 6-11 years on amplitudes of the variability characterized by smaller temporal scales from a few months to 4-5 years. Accounting for scale-specific connectivity in a unified framework leads to complex multigraphs as a possible future research direction.
This study is supported by the Czech Science Foundation, Project No. P103/11/J068.

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No signs of lag-time effects in the connectivity of climate networks constructed with surface temperature anomalies

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The complex network framework has been successfully applied to the analysis of climatological data, providing, for example, a better understanding of the mechanisms underlying reduced predictability during El Nino or La Nina years. Despite the large interest that climate networks have attracted, several issues related to the interpretation of the results remain to be investigated. Here we focus in the information represented by the links of climate networks constructed via similarities of surface air temperature anomalies. Specifically, we study the effect of data time-shifting in the network topology. To analyse the influence of the common forcing represented by the solar annual cycle we shift the time series in each pair of nodes such as to superpose their seasonal cycles. In this way, when two nodes are located in different hemispheres we are able to quantify the similarity of temperature anomalies during the winters and during the summers. We find that data time-shifting does not affect the network connectivity in any significant way; it results only in small variations of local connectivity. This is an unexpected property of the climate network that calls for a revision of the physical meaning of the long range links (tele-connections) in networks constructed via similarities of temperature anomalies.

MS27: Multiplex time-varying and evolutive complex networks

Emergence of network features from multiplexity

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Many biological and man-made networked systems are characterized by the simultaneous presence of different sub-networks organized in separate layers, with links and nodes of qualitatively different types. While during the past few years theoretical studies have examined a variety of structural features of complex networks, the outstanding question is whether such features are characterizing all single layers, or rather emerge as a result of coarse-graining, i.e. when going from the multilayered to the aggregate network representation. Here we address this issue with the help of real data. We analyze the structural properties of an intrinsically multilayered real network, the European Air Transportation Multiplex Network in which each commercial airline defines a network layer. We examine how several structural measures evolve as layers are progressively merged together. In particular, we discuss how the topology of each layer affects the emergence of structural properties in the aggregate network.

Stability of boolean multilevel networks

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The study of the interplay between the structure and dynamics of complex multilevel systems is a pressing challenge nowadays. In this paper, we use a semi-annealed approximation to study the stability properties of random Boolean networks in multiplex (multilayered) graphs. Our main finding is that the multilevel structure provides a mechanism for the stabilization of the dynamics of the whole system even when individual layers work on the chaotic regime, therefore identifying new ways of feedback between the structure and the dynamics of these systems. Our results point out the need for a conceptual transition from the physics of single-layered networks to the physics of multiplex networks. Finally, the fact that the coupling modifies the phase diagram and the critical conditions of the isolated layers suggests that interdependency can be used as a control mechanism.

Time-varying directed networks from EEG signals

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Complex network theory has been largely used in neuroscience, where brain networks are typically constructed from either anatomical and functional neuroimaging data. Brain networks in healthy subjects have been demonstrated to exhibit non-trivial topological properties related to optimal information processing, i.e. small-world, scale-free, etc. whereas diseased brains typically show a critical deviation from such optimal architectures. The large part of these brain networks were constructed by integrating information over a relatively long time period (in the order of seconds), thus neglecting the transient connectivity changes, which in the case of task performances could instead reveal critical dynamics. In the present work, we propose a method to construct time-varying brain networks from EEG signals by means of recursive Kalman-based Granger causality estimates. The method is then validated on a group of healthy subjects during a motor task performance to reveal the brain network dynamical changes at a very high temporal resolution. Results showed that during the preparation of the movement the brain network showed a transient economical small-world property reflecting an optimal balance between topological organization and connection density.

Multiple opinion leaders in a multi-layer social network

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The social network in which individuals are enmeshed influence their opinion formation and therefore their political choices. For this reason it has been a classic theme of research in sociology and political science. Here we identify opinion leaders in an online social network and observe that their impact on users changes in function of the social interaction considered. To that effect we can understand the online social network as a multi-layer network, where at each layer a different interaction takes place. We observe that different opinion leaders emerge at each level highlighting the need to consider all the different interactions when studying such social networks.

MS28: Control of nonlinear systems

Application of act and wait control to oscillatory network desynchronization

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We propose the algorithm for desynchronization of globally coupled oscillators. The problem is actual for neuroscience, where the suppression of pathological neuronal synchronization may remove the symptoms of various diseases. Our algorithm consists of two stages. In the first stage, we measure and memorize the output of the control-free system. In the second stage, we apply the feedback control using the memorized signal. Operation of the algorithm is demonstrated by numerical experiments with all-to-all coupled Landau-Stuart oscillators and Hodgkin-Huxley neurons. From these experiments we found that it is possible to implement charge balance condition for Hodgkin-Huxley network. In the limit of infinite large population of Landau-Stuart oscillators some analytical estimations are derived. Our approach is particularly important for applications to physical and biological systems which do not allow for a simultaneous registration and stimulation at the same time.

Granular fronts in parametrically forced shallow granular layers

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We present an experimental and theoretical study of the granular front formation process of standing subharmonic waves in a fluidized quasi-one-dimensional shallow granular bed. The fluidization process is driven by means of a time-periodic air flow, analogous to a tapping type of forcing. Measurements of the subharmonic instability curve for the homogeneous layer are performed, and the subharmonic amplitude of the critical mode close to the transition is characterized to be found in quite good agreement with those inferred from a universal stochastic amplitude equation. This allows us to determine both the bifurcation point of the deterministic system and the corresponding noise intensity. For larger amplitudes of the forcing, a localized structure develops over the granular layer connecting to regions of the uniform layer oscillating in out-of-phase, which we term a granular front. We propose a simple phenomenological model to describe the dynamics, stability and bifurcation diagram of such structures, which is found in good agreement with experimental observations.

Beyond the odd number limitation: Control matrix design for time delayed-feedback control algorithm

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Time-delayed feedback control (TDFC) algorithm [1] is an efficient tool for stabilization of unstable periodic orbits of nonlinear dynamical systems. The method has been successfully implemented in number of experimental systems [2]. However, Nakajima [3] proved the theorem, which states that the method is unable to stabilize unstable periodic orbits with the odd number of real Floquet multipliers greater than unity. This odd number limitation (ONL) theorem has been commonly accepted by scientific community, but ten years later after Nakajima's proof Fiedler et al. [4] have demonstrated by a simple example that the ONL theorem does not hold for autonomous systems. Recently, the corrected ONL criterion has been introduced by Hooton and Amann [5]. Here we show how this new criterion is related with the phase response curve of the periodic orbit [6] and propose a coupling matrix design algorithm that bypasses the corrected ONL theorem. We demonstrate our algorithm with specific examples of the Lorenz and Chua chaotic systems for which we construct non-diagonal time delayed feedback control matrices, which enable the stabilisation of their periodic orbits with the odd number of unstable positive Floguet multipliers.

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Optimal control of nonlinear dynamics: Quantum-classical correspondence

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Controlling microscopic states is one of the purpose to study chemistry and physics [1], where the optimal control theory (OCT) is known as one of the prominent approach to quantum steering and has been used to design the control field. On the other hand, the Ott-Grebogi-York (OGY) approach [2] is known as the method of controlling chaotic dynamical systems, where unstable periodic orbits found in chaotic systems play an important roll in controllability of the system. Thus, the relation between controlability and chaoticity is one of the old problem in nonlinear physics. Since these two approaches are completely different each other, however, it is difficult to compare properties in them.

In order to analyze controlled dynamics, our idea here is to use a control scheme applicable to both of quantum and classical mechanics. Zhu, Botina, and Rabitz (ZBR) [3] introduced a functional for quantum OCT problems, by which a rapidly convergent iteration scheme is given. Based on this idea, in this contribution, we analyze the problem from a viewpoint of the quantum-classical correspondence. A formal correspondence is known between representations by the density function in classical phase space and the density matrix in quantum mechanics. By the use of this representation, the ZBR functional is also applied to classical optimal control processes.

In our previous work [4, 5], we have shown that an analytic field works efficiently for quantum states in the limit of the long control time. In spite of the formal correspondence between quantum and classical densities, it is still unknown whether we can observe correspondence also in controlled dynamics. In this poster presentation, we will discuss the correspondence on the basis of numerical results in quantum and classical controlled dynamics.

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MS29: The critical role of dynamics in hearing

The understanding of natural auditory systems would be a great step forward in biophysics and biomathematics. However, this goal faces an important difficulty: the inherent complexity of the ear and the auditory cortical responses are currently far from being well understood. This minisymposium is being set up to discus the importance of relatively low-dimensional dynamical systems for tackling the problem of hearing and the complexity of the auditory system.

Organizers: *J. Cartwright and R. Stoop*

Stochastic resonance in a full model of the peripheral auditory pathway

Stefan Martignoli[1], *Florian Gomez*[2] *and Ruedi Stoop*[3]

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The understanding and modeling of the peripheral hearing system (cochlea, outer and inner hair cells, auditory nerve and the lowest auditory nuclei) is a biophysics and scientific computing challenge. We have developed such a framework with real-time capacity. The model not only allows for a selective tuning towards desired sound components in cocktails of sounds. It, moreover, demonstrates the complicated change the auditory signal undergoes on its way higher up the auditory pathway. One intriguing property of the model is that it exhibits that the auditory pathway uses stochastic resonance, in order to relay the sound information gathered and generated in the cochlea higher up the auditory pathway in the most faithful way. Nontrivial manifestations of stochastic resonance in biology are extremely rare. In our case, the effect seems to express an explicit desire of the biological system to maintain artificial auditory signal components that are generated by the cochlear nonlinearities, the purpose of which at the moment we can only speculate on. A side-effect is, however, that it explains the surprising large degree of noise that we find in the firing of the neurons of the auditory nerves.

From physiology to psychophysics to electronics: The role of nonlinear dynamics in pitch perception

Diego Luis Gonzalez[1], *Julyan Cartwright*[2] *and Oreste Piro*[3]

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In the last years it is becoming clear that nonlinear dynamics plays a fundamental role in perception, and in particular in hearing. Very important phenomena such as cochlear compression or otoacoustical emissions, found a unique and plausible physical explanation in the realm of nonlinear dynamics. In fact, a Hopf bifurcation and nonlinear induced or sustained self-oscillations are respectively at the basis of both phenomena [1, 2]. Such fact is indeed not surprising if we take into account the highly nonlinear character of both neuronal processing and the mechano-electrical transduction processes working at the level of the cochlea. However, and surprisingly, has been also uncovered a relevant role of nonlinear dynamics at a psychoacoustic level, and more precisely, regarding the pitch perception of complex sounds [3, 4]. There is still a strong and diffused feeling that most of the outstanding capabilities of our hearing system are consequence of complex neuronal process at high levels of the nervous system, in particular, at the auditory cortex. Nonlinear dynamics is strongly challenging this view showing that simple, low-dimensional, nonlinear systems, should be used as models for describing complicated signal processing of perceptive signals and high level perceptual parameters extraction. In this presentation we illustrate such results showing also that complex capabilities of our auditory system, such our capability to recognize and appreciate music, can be accurately described. In fact, pitch detection is at the basis of music perception and many different, apparently complex, analysing tasks can be performed on the basis of pitch. Moreover, from an evolutionary point of view, pitch offers a relevant advantage: allows to identify the many components of a complex sound as arising from a unique sound source; moreover, on the basis of pitch, such unique source can be classified and separated, for example, for communicative scopes with members of the same species, for evading sudden attacks from predators, or, on the contrary, for localizing preys by the sounds they produce. From such evolutionary point of view, it is clear that simpler animals with simpler auditory systems are anyway capable of coping fruitfully with their acoustic environment, implying that such simpler systems posses also powerful and universal hearing capabilities. Thus, the high complexity characteristic of mammal ears is not mandatory for implementing such universal auditory capabilities. In this line of though, we can envisage the development of technological applications implementing auditory capabilities similar to their biological counterparts. In designing such applications, the use of the same strategy used for developing nonlinear models of complex systems, that we call qualitative or minimal modelling, has revealed to be very useful. Nonlinear dynamics, together with these new modelling strategies, represent a relevant change of paradigm in the modelling of complex biological systems. Theoretical and experimental results confirm largely this approach for dealing with the complexity of actual hearing systems.

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Dynamics of otoacoustic emissions in lizards

Oreste Piro

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It is now widely accepted that the hearing of tetrapods including humans is enhanced by an active process that amplifies the mechanical inputs associated with sound, sharpens frequency selectivity, and compresses the range of responsiveness. The most striking manifestation of such active process is spontaneous otoacoustic emission (SOAE), the unprovoked emergence of sound from an ear. Hair cells, the sensory receptors of the inner ear, are known to provide the energy for such emissions; it is unclear, though, how ensembles of such cells collude to power observable emissions. Tokay geckos are a convenient biological model to study this phenomenon due the outstanding robustness and stability of the SOAEs that they produce. In addition, the anatomy of the lizards hearing organ (papilla) is relatively simpler than other species of the superclass including our own cochlea. These features makes gecko ideal to examine both experimental and theoretically several hypotheses on the dynamical origin and characteristics of SOAE's under the light of models consisting of tonotopic arrays of coupled nonlinear self-oscillators, each one representing an elemental cluster of hair cells in the papilla emitting at a particular frequency of the hearing range. In this contribution, I will review the main results on the characteristics gecko SOAE's experimentally recorded and, using a van der Pol formulation for the above mentioned model oscillators we examine the factors that influence the cooperative interaction between oscillators. In particular, we draw interesting conclusions above the nature of the coupling between the emitting units that make the output of the model compatible with the experimental observations.

Fish: how do they hear; and how do they make their ears?

Julyan Cartwright

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I discuss work in progress on understanding the physics of hearing in fish; work both on how fish hear (they have otoliths -hearing stones- rather than the cochlea we mammals possess), and on how the fish hearing system develops: the physical mechanisms of self-assembly involved in the developmental biology.

MS30: From the neuronal systems to the brain

Causal estimates in the presence of mixed and colored noise

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MEG and EEG data are a mixture of essentially unknown dependent and independent sources. Estimates of dynamical relations are heavily confounded by mixing artifacts and different signal to noise ratios. In this talk I will review the problem and discuss to what extent inverse solution can be considered a remedy. The 'Phase Slope Index' is a measure of temporal relationships, which cannot be generated by instantaneous mixtures of independent sources. I will discuss possibilities and limitations of the Phase Slope Index in comparison to Granger Causality for linear and nonlinear simulated data and for real MEG and EEG data. As a general approach to address the mixing problem I discuss the possibility to exploit temporal order by analyzing time inverted data which should lead to inverted causal directions if, as is claimed for various causal measures, the estimated direction is based on the principle that the cause precedes the effects.

Shadows of early development on brain's functional network: An exploratory study on complex brain networks in preschool years (3-4 years)

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BACKGROUND: The brain, often considered the most complex system in the known universe, is densely interconnected with constituent spatially distinct brain areas, and this subserves as the substrate for the formation of a functional network that are likely to be associated with human cognition. On the advent of advanced neuroimaging techniques coupled with the recent resurgence of the mathematics of graph theory, there has been an explosion of interest to characterise the underlying functional brain network patterns by quantifying the topology of the network in terms of graph theoretic measures. Interestingly, spontaneous brain activity without any concomitant task represents consistent functional network patterns that are increasingly believed to be crucial in understanding the functioning of human brain. However we know very little about these network patterns of very young children in preschool years, yet this reflects a period of intensive mental and behavioural growth associated with dramatic changes in brain's anatomical and physiological substrates.
AIM: The primary objective of this study is the characterization of functional network patterns of spontaneous brain activities in preschool children, and the second objective is to investigate a link between the specificity of network patterns and cognitive development.
MATERIALS & METHODS: Eighty eight children (42 girls, age range of 36-58 months) participated in the study. A MEG with 151 sensors that was specially designed for children was used. The children were watching a video cartoon while their MEG data (3 min) were recorded. The children were also assessed by the Kaufman Assessment Battery for Children, a standard psychological diagnostic test for evaluating cognitive development. The scores on the following categories (constituent sub-categories) were obtained: Sequential Processing Scale (Hand Movement, Number Recall), Simultaneous Processing Scale (Magic Window, Face Recognition, Gestalt Closure), Achievement Scale (Expressive Vocabulary, Arithmetic, Riddle). After suitable preprocessing and artefact elimination, MEG data were bandpass filtered into seven standard EEG/MEG frequency bands (delta 1-4 Hz, theta 4-7 Hz, alpha-1 7-10 Hz, alpha-2 10-13 Hz, beta-1 13-18 Hz, beta-2 18-30 Hz, and gamma 30-70 Hz). For individual frequency band, bivariate phase synchrony measure was applied to construct the functional brain network that was subsequently characterized in terms of graph theoretic measures like shorter path length, clustering coefficient, modularity. Statistical analysis was performed after grouping the sensors according to broadly defined brain regions, distance between sensors (short- and long-range). We applied both factorial and correlational analysis.
RESULTS & DISCUSSION: First we observed a developmental trend from more localized connectivity and shorter path in 3 yrs to more expressed functional connections between spatially distant brain regions in 4 yrs, and the effect was prominent in lower to medium frequencies (delta, theta, alphas). Girls showed shorter path length over long distances across hemispheres than boys in beta-2 band. The patterns of correlations between network measures and different cognitive scores are quite complex, however, the most consistent findings were observed in the left posterior beta band network, possibly signifying a better management and allocation of attentional resources. These results, altogether, demonstrate the usefulness of complex network analysis in evaluating the functional development of the brain and mental performance.

Classification of ADHD patients from EEG patterns of functional connectivity using Bayesian networks

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Functional brain connectivity has proven a useful concept to analysis the cooperative behavior among brain areas. A very recent and promising line of research in this field consists in using the $N \times N$ matrix of a bivariate interdependence indexes, calculated between neuroimaging signals, as the input feature vector for machine learning classification [1, 2]. Here, we apply this idea to classify a group 34 of human subjects as either control healthy ones or ADHD patients from their patterns of EEG functional connectivity. Concretely, for each subject, 8 EEG channels were sample at 256 Hz during two situations,c open (OE) and closed eyes CE). Stationary, artifact-free segments of 5120 samples were filtered in three frequency bands: $\theta\,[3.5-8Hz), \alpha\,[8-13Hz)$ and $\beta\,[13-30Hz]$. Then, the normalized mutual information (MI) was calculated between any two channels i and j $(i, j = 1, \ldots, 8; i \neq j$ for the broad band (unfiltered) data and any of the three frequency bands, thereby obtaining 8 squared symmetric interdependence matrixes of 8×8 elements each. Additionally, from each of these matrixes, the nonlinear correlation information entropy I_E was also calculated as described in [3].
We then used a Bayesian network as classifier. It is a probabilistic graphical model that represents the features and their conditional dependencies as a directed acyclic graph (DAG) where a node represents a feature and edges represent conditional dependencies between two features. The input data was discretized by means of Fayyad-Irani's MDL discretizer method [4], which is an entropy-based top-down partitioning strategy that recursively splits intervals at the point where the information gain, (defined as the difference between the information value with and without the split) is the largest. As stopping criterion, it uses the Minimum Description Length (MDL) principle, which provides a way to select the hypothesis with the best compression achieved.
For the case of the normalized MI index, we carried out a feature selection procedure to select the subset of features that are fit for classification. Specifically, we used the symmetrical uncertainty measure (SU), defined as [4]:

$$SU(X,Y) = 2\Big[\frac{I(X,Y)}{H(X)+H(Y)}\Big]$$

Where $I(X, Y)$ is the MI between feature X and Y, and $H(.)$ stands for entropy. A value of 1 indicates that knowledge of X completely predicts the value of the Y, whereas a value of 0 indicates that they are independent. A conservative strategy is to discard those with $SU = 0$. With this criterion and applying FCBF [5] to remaining features, 6 features were selected as relevant for the classification task, which give rise to an accuracy of 83.35 ± 17.65 as estimated by-known leave-one-out-cross-validation algorithm. In contrast, classification using the 8 I_E values produce a mere 55.9 ± 44.12 (corresponding to all individuals classified in the same class).
We conclude that the combination of data filtering, functional connectivity indexes and a feature selection procedure allows a good classification accuracy using a Bayesian network, which supports the hypothesis that EEG brain connectivity patterns can be successfully used to distinguish healthy from non-healthy human subjects.

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Anticipated synchronization in cortical circuits

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Synchronization of nonlinear systems has been studied extensively in a large variety of physical and biological systems and many kind of synchronization schemes, including complete synchronization, phase synchronization or generalized synchronization, among others, have been observed. In particular, if two dynamical systems are coupled in a drive-response configuration, an intriguing and unintuitive type of synchronization, termed anticipated synchronization (AS), can occur. For some dynamical systems stable AS can be observed if the response system is subject to a negative self-feedback. The occurrence of AS in these systems depends mainly on the coupling strength and the delay time. Examples include chaotic oscillators, optical systems or delay-coupled maps, among others. In models of neuronal systems AS can be observed when delayed self-feedback and gap junctions are considered or the self-feedback is originated by assuming some coupling through inhibitory neurons. In the latter, an explicit delay in the response system is not required if chemical coupling is assumed; the intrinsic delay induced by the rise and fall times of the synapse provide the necessary ingredient. In this presentation we show that if we couple two neuronal populations in a drive-response configuration and the response population contains, or is connected to, a group of inhibitory neurons AS can occur. This means that the response system can lead, under certain circumstances, the driver population. We find that for a large range of inhibitory-coupling values the response system predicts the activity of the driver's one, while for other values the commonly known delayed synchronization occurs.

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GENERAL INFORMATION

The Conference venue

The sessions will take place in Building 1 of the School Computer Science (Facultad de Informática-Bloque 1) in the Campus of Montegancedo (Pozuelo de Alarcón), which is 15 km from the center of Madrid.
The address is:
Facultad de Informática
Campus de Montegancedo
28223 Pozuelo de Alarcón, Madrid, Spain
Tel: +34 91336 4633 / +34 91336 4660

Madrid-Barajas Airport is 12 kilometers northeast of the city. For more information on Barajas airport please visit the website
http://www.aena-aeropuertos.es/csee/Satellite/Aeropuerto-Madrid-Barajas/en/Home.html.

- **Underground** Metro line 8 runs from all the airport terminals to *Nuevos Ministerios* station in central Madrid. Estimated travel time: 12-15 minutes. The underground does not reach the Conference Venue, but goes from the airport to the center of the city. The nearest stations are Gregorio Marañon (Metro line 7 and 10) for the hotels NH Zurbano and NH Abascal and Rios Rosas (Metro line 1) for NH Prisma. A map of Madrid Metro will be provided at registration, but you can download it from here http://www.metromadrid.es/en or http://goo.gl/zIJZP.
- **City bus** Several bus lines run from the airport to central Madrid. City bus route 200 runs from Madrid-Barajas airport terminals T1, T2, T3 and T4 to the *Avenida de América* Transport Hub, where there are connections to several city and intercity bus routes and the Madrid Metro system.
- **Train** A modern suburban train line (*Cercanias*) connects Terminal T4 with several key locations in Madrid: *Chamartin*, *Nuevos Ministerios*, *Recoletos*, *Atocha* and *Principe Pío*. Estimated travel time: 22 minutes from/to Recoletos (the closest train station to the official hotels). Do not buy *Cercanias* tickets in advance, as tickets can only be used within 2 hours following their purchase!!

  Check timetables and fares at http://www.ctm-madrid.es
- **Taxi** All airport terminals have clearly signed taxi ranks outside the arrivals area. Official taxis are white with a red stripe and the coat-of-arms of Madrid City Council on the doors. Ignore unsolicited driving offers inside terminals. Make sure that the taxi driver has started up the taximeter at the start of the journey (minimum fare). Ask for the bill in case of any complaint. The cost from airport to city center should be approximately 40 euros. Airport fares include a supplement which in 2013 is 5.50 euros, but there is no supplement for luggage.

  Taxi Reservations: 0034 91547 8200 (http://www.radiotelefono-taxi.com)

How to reach the Conference venue

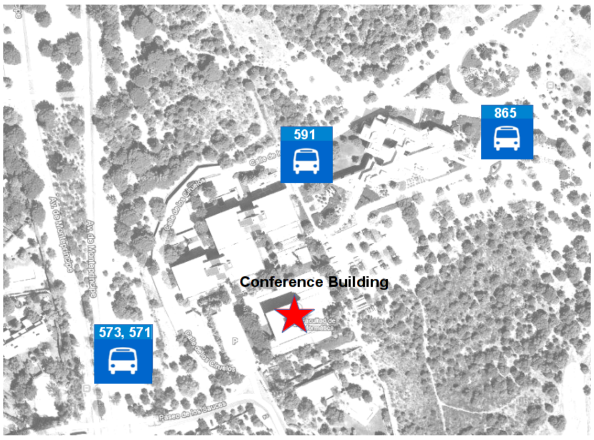
Conference bus service A bus service will be available every day in the morning from the conference hotels to the Conference venue, and back in the evening. The service is available for all the participants, not just for those staying at the recommended hotels. The meeting point for the five buses will be in front of NH Suites Prisma (*Santa Engracia St.*), and the departure time will be at 7:50 am. Consult the program timetable in the Book of Abstracts for the return time.

Alternatives: using public transportation Public transportation in Madrid is fast, safe, and not very expensive. Nevertheless, the Conference Bus Service will be faster than any alternative. For those who wish to get to the conference by their own means, two possible routes are available (around 45 minutes):

1. Take Metro line 10 to *Colonia Jardin* (direction to *Puerta del Sur*). From here, you can choose:
    - Bus 591 and step down at the last stop, *Facultad de Informatica*.

- Buses 571 or 573 and step down at *Av. Monteprincipe - Facultad de Informatica*, then walk approximately 250 m to the Computer Science building (Bloque 1).

2. From *Plaza Cardenal Cisneros* or Metro station *Ciudad Universitaria*, take bus 865, directly to the campus. Step down at last stop *Facultad de Informatica*.



To check the updated timetables of suburban buses 571, 573, 591 and 865 please consult the web http://www.ctm-madrid.es.

By car Exit the M-40 at junctions 36 (northbound) or 38 (southbound). Directions: 40°24'22.82"N, 03°50'19.86"O

Public transportation fares

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You can also buy a multi-trip pass (called *metrobus*) at the ticket machines in the lobby of any Metro station (most of them accept cash and visa), and in tobacconists and authorized news-stands in Madrid. There are two types of *metrobus*:
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- Valid for 10 Metro trips in zone A, in EMT city buses (except the Linea Expres to and from the airport): 12.2 euros.
- Valid for 10 Metro trips and EMT city bus trips (except Linea Expres) with a single transfer from EMT to EMT in a maximum of 60 minutes from the first validation: 18 euros.

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- Buses 865 and 591 require a Zona B1 ticket. Cost: 2 euros.
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Tourist pass It is the easiest, most convenient and cheapest way to get around the Madrid region. This pass gives you unlimited access to all forms of public transport. The tourist ticket voucher is provided together with the instructions for its use in Spanish and English, as well as maps of the Metro and rail network, a Madrid street map and a map of the Community of Madrid with indication of the means of transport and the main points of interest.
There are five kinds of season tickets: for 1, 2, 3, 5 and 7 calendar days. The validity of the tourist passes is counted by calendar day; the day the first journey is made is the first day of use. As our

service operates from 06:00 to 01:30 hours, the calendar days match up with this same timetable. The expiry date of the pass is printed on the back of the coupon.
They may be acquired at all stations in the Metro network, terminals T1, T2, T3 at Barajas Airport, Office of Tourism (Plaza Mayor, 27), places of tourist interest and hotels.

Preparing your contribution

The program is organized around thirteen invited plenary talks, six sessions of minisymposia, four contributed sessions and one poster session scheduled on Tuesday afternoon.

Talks
The lecture rooms will be equipped with a projector with standard VGA input and a Windows computer with Powerpoint software, although it is strongly recommended to bring the presentation converted to pdf to avoid font and formatting problems. Please, **upload your presentation to the computer 30 minutes before the session begins**. For those wishing to use their own machine, testing should also be done prior to the session.
Remember that the duration of the talks are:

- **Invited plenary talks** 45 min including 5 min discussion.
- **Minisymposia talks** 30 min, including 5 min discussion.
- **Contributed talks** 20 min, including 5 min discussion.

Posters
Will be on display throughout the entire event and can be affixed as early as Monday morning. Poster boards will be numbered. Please hang up your poster on the corresponding board with the number that matches the one assigned in the conference booklet. Tape will be provided at the Conference desk. Recommended poster size is **A0** (120 cm $\times$ 80 cm) with portrait orientation. Check the section below for more information.

There will be a series of Best Poster Awards funded by the European Physical Society (EPS) and the Publishing companies participating in the Conference.

The election of the Best Conference Posters will be made by a collaborative filtering method. Together with the conference material each participant will receive a sticker to vote for the Best Poster, which will be placed directly on the poster selected.

The voting process will finish at the end of the poster session (Tuesday 4th) and the awards will be given during the gala dinner (Wednesday 5th).

The sponsors of the Best Poster Awards are:

Royal Society Publishing | www.royalsocietypublishing.org

Taylor & Francis Group | www.tandfonline.com

Springer | www.springer.com

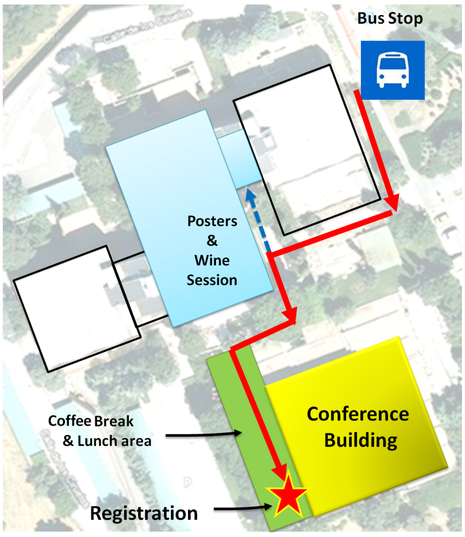
European Physical Society | www.eps.org

During the Conference

The Conference will take place at the Campus of Montegancedo of the Universidad Politécnica de Madrid. The relevant locations are:

- **The Conference Sessions** will be held at the Building 1 (Bloque 1) of the Faculty of Informatics. Check below the information about conference rooms and the facilities inside the building.

- **The Registration** will take place at the porch of Building 1. Please be sure you are in line at the correct desk, especially if you chose to pay directly in cash. For your convenience **there will be a registration office at NH Abascal hotel on Sunday June 2**, from 18:00 to 20:00 h. A badge will be issued only after payment.
- **Coffee and lunch breaks** will take place outdoors, in the porch and the space around the large *jaima* tents placed outside Building 1. This is why you will find a cap as part of your conference materials!
- **The Poster & Wine Session** will be held in the afternoon of Tuesday 4 at the ground floor of Building 3 (Bloque 3), please follow the indications. However, the posters will be displayed all along the Conference. Ask the Organizers for help to place your poster.

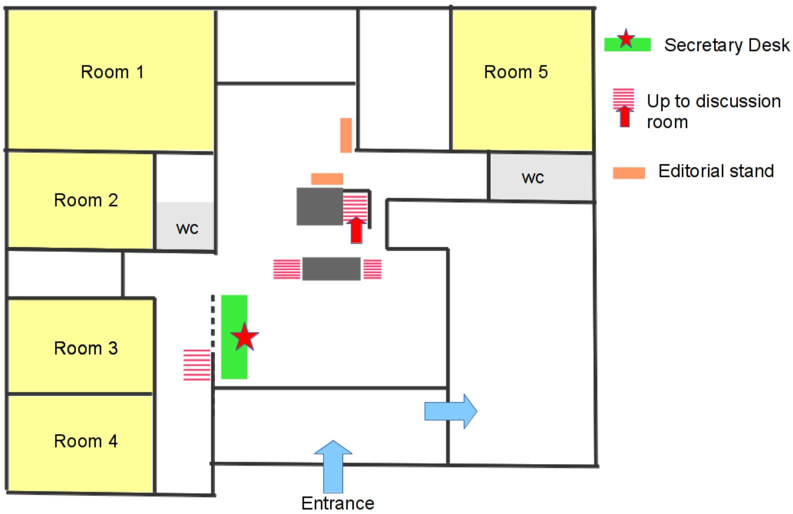


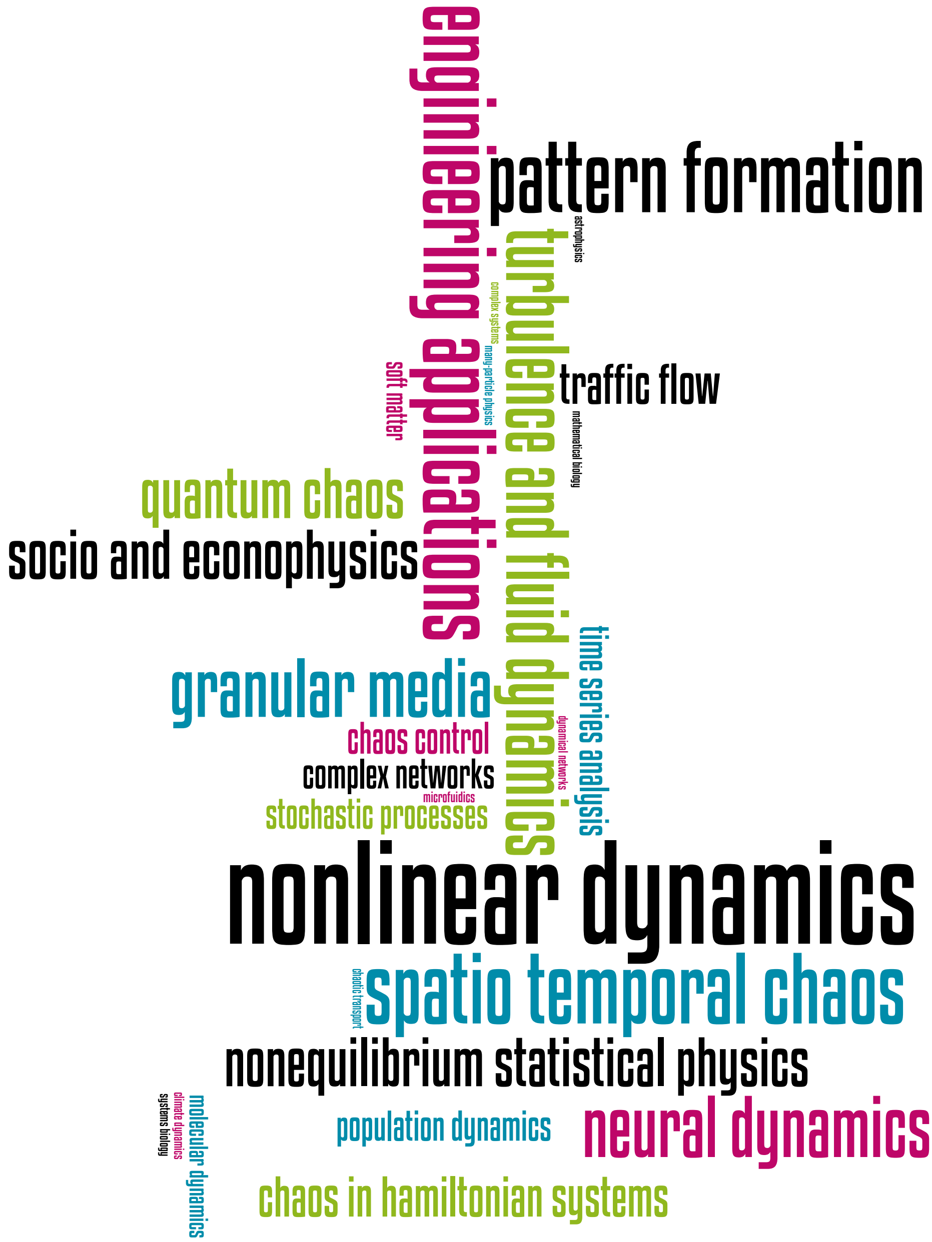
Inside the Conference Building

All the session rooms are placed at the ground floor in the Conference Building. You will find assistance at the Secretary Desk, placed near Room 1.

WiFi connectivity will be available through EDUROAM in all the Conference areas. Pay attention to additional instructions from the Organizers.

An additional room is at your disposal on the first floor of the building.





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