

Biological neuronal networks as deterministic dynamical systems.

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Abstract in the
XVI Conference on Nonequilibrium Statistical Mechanics and Nonlinear
Physics,
MEDYFINOL 2008,
Punta del Este, Uruguay, 2008

ABSTRACT

The network of $n \geq 2$ synaptically connected neurons can be modeled as a deterministic system, and thus studied with the theoretical tools of the Dynamical Systems Theory in a qualitative description, rather than using a quantitative method. Also Ergodic Theory known results are applicable.

The abstract mathematical tools provide rigourously proved properties of some n -neurons system models and the qualitative tasks of its spike trains. Some systems are mathematically proved to exhibit several characteristic structurally stable limit cycles in the evolution of its internal spikes. Those limit cycles are not modified by the external small random perturbations, but the system can jump from one cycle to other when an external excitation spikes some of the sensorial neurons of the system. The system has a response capable of processing a large amount of information from the environment.

XVI Reunión de Mecánica Estadística de No equilibrio y Física No lineal
XVI Conference on Nonequilibrium Statistical Mechanics and Nonlinear Physics

MEDYFINOL'08

Hotel Club del Lago, Punta del Este, Uruguay
 December 1-5, 2008

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Acknowledgements

We wish to thank the following institutions for their contribution to the success of this conference:

- Centro Latinoamericano de Física (CLAF)
- Office Naval Research Global (USA)
- European Physical Society, Interdivisional Group of Physics for Development (IGPD)
- The Abdus Salam International Centre for Theoretical Physics (ICTP), Italy
- Facultad de Ingeniería, Universidad de Los Andes, Chile
- Anillo de Ciencia y Tecnología ACT15, Chile
- Comisión Sectorial de Investigación Científica (CSIC), Uruguay
- Programa de Desarrollo de las Ciencias Básicas (PEDECIBA), Uruguay.

PROGRAM

Sunday, November 30

17:00 – 20:00 Registration

Monday, December 1

08:00 – 09:00 Registration

08:55 – 09:00 Opening Remarks

Chair: **Cristina Masoller**

- 09:00 – 09:30 **Ezequiel Albano** (La Plata, Argentina): *Dynamic Behavior of the 1D Ising Ferromagnet with long-range interactions*
- 09:30 – 10:00 **Ian Levin** (Porto Alegre, Brazil): *Collision-less relaxation in non-neutral plasmas and gravitational systems*
- 10:00 – 10:30 **Andrea Rapisarda** (Catania, Italy): *Chaos and nonergodic dynamics in long-range interacting systems*

10:30 – 11:00 Coffee break

Chair: **Arturo Marti**

- 11:00 – 11:30 **Katja Lindenberg** (San Diego, USA): *Continuous time random walk for open systems: Fluctuation theorems and counting statistics*
- 11:30 – 12:00 **Alexander Blumen** (Freiburg, Germany): *Continuous time quantum walks on complex networks*
- 12:00 – 12:30 **Manuel Caceres** (Bariloche, Argentina): *Evolutionary formalism from random Leslie matrices*
- 12:30 – 13:00 **Gerardo Garcia-Naumis** (UNAM, Mexico): *Thermal relaxation and low frequency vibrational anomalies in simple models of glasses: a study using non-linear Hamiltonians*

13:00 – 14:00 Lunch

Chair: **Orazio Descalzi**

- 15:00 – 15:30 **Hernan Solari** (Buenos Aires, Argentina): *Lessons from a mathematical model for the big Yellow Fever epidemic (Buenos Aires, 1871)*
- 15:30 – 16:00 **Marcel Clerc** (Santiago, Chile): *Interaction and coarsening dynamics of dissipative soliton in parametrically driven Newtonian fluid*
- 16:00 – 16:30 **Harald Pleiner** (Mainz, Germany): *Influence of sedimentation on convective instabilities in colloidal suspensions*
- 16:30 – 17:00 **Helmut Brand** (Bayreuth, Germany): *Influence of boundary conditions on localized solutions of the cubic-quintic Complex Ginzburg-Landau Equation*

17:00 – 17:30 Coffee break

Chair: **Osvaldo Rosso**

- 17:30 - 17:50 **Orazio Descalzi** (Santiago, Chile): *Noise induces partial annihilation of colliding dissipative solitons*
- 17:50 - 18:10 **David Laroze** (Arica, Chile): *Amplitude equation for stationary convection in viscoelastic ferrofluid*
- 18:10 - 18:30 **Hector Mancini** (Pamplona, Spain): *Dynamics, control and synchronization in Benard-Marangoni convective patterns*
- 18:30 - 18:50 **Marta Rosen** (Buenos Aires, Argentina): *Rayleigh-Plateau instability produced with gravity oscillation*
- 18:50 - 19:10 **Alexey Snezhko** (Argonne, USA): *Pattern formation and complex dynamics in driven magnetic granular ensemble*
- 19:10 - 19:30 **Günter Radons** (Chemnitz, Germany): *Lyapunov modes in extended systems*
- 19:30 - 19:50 **Daniel A. Vega** (Bahía Blanca, Argentina): *Block copolymer pattern alignment induced by substrate topography*

20:30 **Welcome drink**

Tuesday, December 2

08:30 - 09:00 **Registration**

Chair: **Miguel Arismendi**

- 09:00 - 09:30 **Peter Hanggi** (Augsburg, Germany): *The ring of Brownian motion: Stochastic resonance and ex(e/o)rcising demons with Brownian motors*
- 09:30 - 10:00 **Marcia Barbosa** (Porto Alegre, Brazil): *The generic mechanism for water-like anomalies*
- 10:00 - 10:30 **Roberto F. S. Andrade** (Bahia, Brazil): *Scaling properties of fluid flow in a porous media: a model based on Apollonian packing*

10:30 - 11:00 **Coffee break**

Chair: **Marcia Barbosa**

- 11:00 - 11:30 **Gabriel Mindlin** (Buenos Aires, Argentina): *The physics and neural control of birdsong*
- 11:30 - 12:00 **Dante Chialvo** (Chicago, USA): *Galileo was right, also about tonal consonance*
- 12:00 - 12:30 **Miguel Arismendi** (Mar del Plata, Argentina): *Converting genetic network oscillations into somite spatial pattern*
- 12:30 - 13:00 **Maximino Aldana** (Morelos, Mexico): *Critical dynamics in genetic networks: examples from four kingdoms*

13:00 - 14:00 **Lunch**

14: 00 **Poster Session I**

Chair: **Raul Rechmann**

- 15:00 - 15:30 **Celso Grebogi** (Aberdeen, UK): *Fractal skeletons: the universality in death by starvation*
- 15:30 - 16:00 **Frank Schweitzer** (Zurich, Switzerland): *Non-linear voter models: The transition from invasion to coexistence*

- 16:00 – 16:30 **Emilo Hernandez-Garcia** (Mallorca, Spain): *Species clustering in models of biological competition*
- 16:30 – 17:00 **Francesc Sagues** (Barcelona, Spain): *Physics of colloids: from collective assemblies to single swimmers*

17:00 – 17:30 Coffee break & Poster Session I

Chair: **Gabriel Mindlin**

- 17:30 – 17:50 **Miguel Hoyuelos** (Mar del Plata, Argentina): *Nonequilibrium entropy of Markov processes*
- 17:50 – 18:10 **Adriano Batista** (Campina Grande, Brazil): *AC-driven Duffing oscillators under correlated noise and non-Markovian dissipation*
- 18:10 – 18:30 **Veronica Marconi** (Córdoba, Argentina): *Novel ratchet effects for the motion of elastic interfaces*
- 18:30 – 18:50 **María Florencia Carusela** (Buenos Aires, Argentina): *Induced current in classical and quantum damped ratchets*
- 18:50 – 19:10 **Itzhack Dana** (Ramat-Gan, Israel): *Quantum-resonance ratchets: theory and experiment*
- 19:10 – 19:30 **Jaime Cisternas** (Santiago, Chile): *Stochastic model calculation for the carbon monoxide oxidation on iridium(111) surfaces*

21:30 – 23:00 Poster Session I

Wednesday, December 3

08:30 – 09:00 Registration

Chair: **Sergio Cannas**

- 09:00 – 09:30 **Eleonora Catsigeras** (Montevideo, Uruguay): *Biological neuronal networks as deterministic dynamical systems*
- 09:30 – 10:00 **Marcelo Magnasco** (New York, USA): *Dynamical and statistical criticality in a model of neural tissue*
- 10:00 – 10:30 **Jürgen Kurths** (Potsdam, Germany): *Dynamics on complex networks with time varying topology*

10:30 – 11:00 Coffee break

Chair: **Eleonora Catsigeras**

- 11:00 – 11:30 **Theo Geisel** (Goettingen, Germany): *Self-organized criticality in neuronal systems*
- 11:30 – 12:00 **Sergio Cannas** (Cordoba, Argentina): *Emergent self-organized complex network topology out of stability selection pressure*
- 12:00 – 12:30 **Kunihiko Kaneko** (Tokyo, Japan): *Dynamical systems problems inspired by biology*
- 12:30 – 13:00 **Adi Bulsara** (San Diego, USA): *Coupling nonlinear oscillators for fun and profit*

13:00 – 14:00 Lunch

Chair: **Alejandra Figliola**

- 15:00 - 15:30 **Silvina Ponce -Dawson** (Buenos Aires, Argentina): *Propagation of calcium waves and synaptic plasticity*
- 15:30 - 16:00 **Gustavo Martinez-Mekler** (Cuernavaca, México): *Calcium network dynamics and sperm motility*
- 16:00 - 16:30 **Mario Cosenza** (Mérida, Venezuela): *Generalized synchronization of chaos in autonomous systems*
- 16:30 - 17:00 **Claudio Mirasso** (Mallorca, Spain): *Delayed but still in time: a neural mechanism for zero lag long range synchronization in the brain*

17:00 - 17:30 Coffee break and Poster Session II

Chair: **Silvina Ponce - Dawson**

- 17:30 - 17:50 **Alejandra Figliola** (Buenos Aires, Argentina): *About the effectiveness of different methods for the estimation of the multifractal spectrum of natural series*
- 17:50 - 18:10 **Hilda Larrondo** (Mar del Plata, Argentina): *Quantifiers for stochasticity of chaotic pseudo random number generators*
- 18:10 - 18:30 **Maria Carmen Romano** (Aberdeen, UK): *Traffic jams in the cell: lost in translation*
- 18:30 - 18:50 **Guillermo Solovey** (Buenos Aires, Argentina): *Multiple scales in calcium signals*
- 18:50 - 19:10 **Alexandre Souto Martinez** (São Paulo, Brazil): *Generalized continuous and discrete population dynamics models*
- 19:10 - 19:30 **Raul Rechtman** (Morelos, Mexico): *Complexity of the wind tree model*

21:30 - 23:00 Poster Session II

Thursday, December 4

08:30 - 09:00 Registration

Chair: **Celia Anteneodo**

- 09:00 - 09:30 **Damián Zanette** (Bariloche, Argentina): *Beyond networks: opinion formation in triplet-based social structures*
- 09:30 - 10:00 **Marcel Ausloos** (Liege, Belgium): *Entropy correlation distance method applied to the Gross Domestic Product of rich countries*
- 10:00 - 10:30 **Marta Gonzalez** (Boston, USA): *Understanding individual human mobility patterns*

10:30 - 11:00 Coffee break

Chair: **Damian Zanette**

- 11:00 - 11:30 **Celia Anteneodo** (Rio, Brazil): *Unraveling the stochastic dynamics of financial markets*
- 11:30 - 12:00 **Jose Roberto Iglesias** (Porto Alegre, Brazil): *Crime and punishment: the economic burden of impunity*
- 12:00 - 12:30 **Raul Donangelo** (Montevideo, Uruguay): *Early warnings of catastrophic changes in ecosystems*

12:30 - 13:00 **Jason Gallas** (Porto Alegre, Brazil): *Cascades of hubs and spirals in phase diagrams of simple flows*

13:00 - 14:00 **Lunch**

14: 00 **Poster Session III**

Chair: **Jose Roberto Iglesias**

15:00 - 15:20 **Guillermo Cecchi** (New York, USA): *Topological effects of synaptic time-dependent plasticity*

15:20 - 15:40 **Pablo Balenzuela** (Buenos Aires, Argentina): *Critical functional networks: Similarities between brain dynamics and Ising model*

15:40 - 16:00 **Guillermo Ortega** (Madrid, Spain): *Complex network analysis of human electrocorticographic data*

16:00 - 16:20 **Leonardo Brunnet** (Porto Alegre, Brazil): *Coordinated motion influences typical scales of cell sorting*

16:20 - 16:40 **Marco Idiart** (Porto Alegre, Brazil): *A process of k -max winner take all mediates tuning orientation on cells of the visual cortex*

16:40 - 17:00 **Jorge Mazzeo** (Buenos Aires, Argentina): *Multiscale characteristics of cell proliferation in the developing central nervous system of chick embryos*

17:00 - 17:30 **Coffee break and Poster Session III**

Chair: **Pablo Balenzuela**

17:30 - 17:50 **Raul Montagne** (Recife, Brazil): *Quasi-long-range order in active nematics and background flux*

17:50 - 18:10 **Hugues Chaté** (Saclay, France): *Modeling and understanding active matter: variations on the Vicsek model*

18:10 - 18:30 **Angel Plastino** (Buenos Aires, Argentina): *Aspects of quantum phase transitions*

18:30 - 18:50 **Araceli Proto** (Buenos Aires, Argentina): *Consequences of the dynamical properties of the specific heat in semi quantum nonlinear hamiltonians*

18:50 - 19:10 **Leszek Szybisz** (Buenos Aires, Argentina): *Spontaneous symmetry breaking and first-order phase transitions of adsorbed fluids*

19:10 - 19:30 **Nicolas Wschebor** (Montevideo, Uruguay): *Non-perturbative renormalization group approach to out-of-equilibrium problems*

21:30 - 23:00 **Poster session III**

Friday, December 5

08:30 - 09:00 Registration

Chair: **Francisco Tamarit**

09:00 - 09:30 **Jose R. Rios Leite** (Recife, Brazil): *Time delays in the synchronization of chaotic systems*

09:30 - 10:00 **Tom Gavrielides** (New Mexico, USA): *Mutually coupled semiconductor lasers with rotated optical feedback*

10:00 – 10:30 **Jorge Tredicce** (Nice, France): *Cavity soliton laser based on mutually coupled semiconductor microresonators*

10:30 – 11:00 Coffee break

Chair: **Araceli Proto**

11:00 – 11:30 **Francisco Tamarit** (Córdoba, Argentina): *The storage capacity of a bidimensional Hopfield neural network with complex topology*

11:30 – 12:00 **Ricardo Velluti** (Montevideo, Uruguay): *Auditory neuronal networks in sleep and wakefulness*

12:00 – 12:30 **Alessandro Villa** (Grenoble, France): *Spatiotemporal patterns of activity in cerebral neural networks: a dynamical systems perspective*

12:30 – 13:00 **Claudio Dorso** (Buenos Aires, Argentina): *Community detection in networks*

13:00 – 14:00 Lunch

Chair: **Angel Plastino**

15:00 – 15:20 **Inés Caridi** (Buenos Aires, Argentina): *Clusters in networks with incomplete information: The disappeared in Argentina (1975-1984)*

15:20 – 15:40 **Silvia London** (Bahia Blanca, Argentina): *Convergence across the American countries*

15:40 – 16:00 **Panayotis Panayotaros** (Ciudad de Mexico): *Localized coherent structures in the discrete NLS equation*

16:00 – 16:20 **Jose Suarez-Vargas** (Venezuela): *Synchronization transitions and multistability in the route to oscillation death of coupled nonlinear oscillators*

16:20 – 16:40 **Carlos Argolo** (Alagoas, Brazil): *The threshold of coexistence of a predator-prey probabilistic model in a fractal and in a square lattice*

16:40 – 17:00 **Cesar Sampaio** (Recife, Brazil): *Dynamics of the volatility distributions on Complex Networks*

17:00 – 17:10 Closing Remarks

TALKS

(Alphabetical order)

(INVITED) Ezequiel V. Albano, D. Rodríguez, M. Bab, Instituto de Investigaciones Fisicoquímicas Teóricas y Aplicadas (INIFTA), Facultad de Ciencias Exactas, Universidad Nacional de La Plata, Argentina
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Dynamic behavior of the 1D Ising ferromagnet with long-range interactions

The dynamic behavior of the Ising model, with power-law decaying interactions of the form $1/r^{d+\sigma}$, is simulated in $d=1$ dimension for $\sigma=0.75$, by using the Monte Carlo method. This value of σ is selected because we expect that critical exponents will be far from both the mean-field values $\sigma=0.5$ and the strong Kosterlitz-Thouless behavior. Both the standard relaxation of ordered configurations and the short-time dynamics of disordered configurations are studied and rationalized in terms of scaling arguments. By measuring the time dependence of physical observables, such as the magnetization, susceptibility, Binder cumulant, correlation function, etc, the critical temperature and all the relevant critical exponents can be determined, including the static (β, γ, μ) and the dynamic (z) ones. Also, the scaling exponent of the initial increase of the magnetization is evaluated. Based on this evidence we conclude that the study of the dynamic behavior of the system allows the complete characterization of its critical properties.

(INVITED) Maximino Aldana, Instituto de Ciencias Físicas, UNAM, Morelos, México
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Critical dynamics in genetic networks: examples from four kingdoms

The coordinated expression of the different genes in an organism is essential to sustain functionality under the random external perturbations to which the organism might be subjected. To cope with such external variability, the global dynamics of the genetic network must possess two central properties. (a) It must be robust enough as to guarantee stability under a broad range of external conditions, and (b) it must be flexible enough to recognize and integrate specific external signals that may help the organism to change and adapt to different environments. This compromise between robustness and adaptability has been observed in dynamical systems operating at the brink of a phase transition between order and chaos. Such systems are termed critical. Thus, criticality, a precise, measurable, and well characterized property of dynamical systems, makes it possible for robustness and adaptability to coexist in living organisms. In this talk investigate the dynamical properties of the gene transcription networks reported for *S. cerevisiae*, *E. coli*, and *B. subtilis*, as well as the network of segment polarity genes of *D. melanogaster*, and the network of flower development of *A. thaliana*. By analyzing hundreds of microarray experiments to infer the nature of the regulatory interactions among genes, and implementing these data into the Boolean models of the genetic networks, I will show that, to the best of the current experimental data available, the five networks under study indeed operate close to criticality. The generality of this result suggests that criticality at the genetic level might constitute a fundamental evolutionary mechanism that generates the great diversity of dynamically robust living forms that we observe around us.

(INVITED) Eleonora Catsigeras, Ins. de Matemática. Facultad de Ingeniería, Universidad de la República, Uruguay
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Biological neuronal networks as deterministic dynamical systems

The network of $n \gg 2$ synaptically connected neurons can be modeled as a deterministic system, and thus studied with the theoretical tools of the Dynamical Systems Theory in a qualitative description, rather than using a quantitative method. Also Ergodic Theory known results are applicable. The abstract mathematical tools provide rigorously proved properties of some n -neurons system models and the qualitative tasks of its spike trains. Some systems are mathematically proved to exhibit several characteristic structurally stable limit cycles in the evolution of its internal spikes. Those limit cycles are not modified by the external small random perturbations, but the system can jump from one cycle to other when an external excitation spikes some of the sensorial neurons of the system. The system has a response capable of processing a large amount of information from the environment.

(INVITED) Guillermo A. Cecchi, The Rockefeller University, New York, USA
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Topological effects of synaptic time-dependent plasticity

Connections between individual neurons in the brain arise first from the spatial distribution of axons and dendrites within neural tissue. Local synaptic modification rules are known to shape patterns of connectivity in local neural tissue and local microcircuit topology. Global brain network topology, however, is believed to emerge largely from patterned area to area connectivity determined during development. One proposal for a rule governing this level of organization, the "no strong loops hypothesis", considered only patterning mechanisms to implement its specific area to area network topological constraint. Here, we show that the local Spike Timing-Dependent Plasticity (STDP) rule has the effect of reducing the trans-synaptic weights of closed loops of any length within a simulated network of neurons. We further prove analytically that anti-loop learning and STDP are equivalent for the case of a linear network. Thus a notable local synaptic learning rule yields structures dominated by feed-forward connections at their largest scale. Given its widespread occurrence in the brain, we propose that STDP must be involved in eliminating long range synaptic loops among individual neurons across all brain scales, up to, and including, the scale of global brain network topology.

Hugues Chaté, CEA-Saclay, SPEC, France
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Modeling and understanding active matter: variations on the Vicsek model

The model introduced by Vicsek et al. in which self-propelled particles align locally with neighbors is, because of its simplicity, central to most studies of collective motion or "active" matter. After reviewing briefly its main properties, we show how it can be expanded into three main directions: changing the symmetry of the particles and/or of their interactions, adding local cohesion, and taking into account the fluid in which the particles move.

List of Participants

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Marcelo Alves Pereira, São Paulo, Brazil
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