DDAYS 2016

Salou, 9-11 de noviembre de 2016

Octava reunión bienal de la red temática DANCE (Dinámica, Atractores y No linealidad. Caos y Estabilidad)

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La inscripción incluye comidas y cenas.

Horario de comidas: de 13:00 a 15:00.
Horacio de cenas: de 20:00 a 22:00.

Wifi libre (sin password) en todo el hotel.

HORARIO

Miércoles, 9 de noviembre

13:00 - 15:00 Almuerzo

15:00 - 18:30 Sesión científica: Estados de transición
Responsables: Florentino Borondo (UAM)
Fabio Revuelta (UPM)

15:00 - 15:30 *La química del TS*
Florentino Borondo (UAM)

15:30 - 16:00 *Geometría del Estado de Transición en medios condensados con campos externos.*
Fabio Revuelta (UPM)

16:00 - 17:00 *Variedades al borde de la ruptura hiperbólica.*
Alex Haro (UB)

17:00 - 17:30 **Café**

17:30 - 18:30 *Teoría Variacional del Estado de Transición: Fundamentos y aplicaciones a las reacciones químicas y bioquímicas.*
Josep Maria Lluch (UAB)

20:00 - 22:00 Cena

Jueves, 10 de noviembre

09:30 - 13:00 Sesión científica: Mecánica celeste
Responsable: Victor Lanchares (UNIR)

09:30 - 10:30 *Constelaciones de satélites artificiales y posibles aplicaciones*
Daniel Casanova (CUD - UNIZAR)

10:30 - 11:00 **Café**

11:00 - 12:00 *Global flow of the parabolic restricted three-body problem*
Josep Maria Cors (UPC)

12:00 - 13:00 *Dynamics of a particle in some cases of the N-body problem*
Antonio Elipe (UNIZAR)

13:00 - 15:00 Almuerzo

15:00 - 18:00 Sesión de tesis
Responsables: Alex Haro (UB)

15:00 - 15:20 *Monomial multisummability through Borel-Laplace transforms. Applications to singularly perturbed differential equations and Pfaffian system*
Sergio Carrillo (UVA)

15:20 - 15:40 *Local uniformization of codimension one foliations. Rational archimedean valuations*
Miguel Fernández Duque (UVA)

15:40 - 16:00 *Analytical tools to study the criticality at the outer boundary of potential centers*
David Rojas (UAB)

16:00 - 16:20 *Numerical computation of invariant objects with wavelets*
David Romero (UAB)

16:20 - 16:40 *A precession model explaining warped galaxies*
Patricia Sanchez-Martin (URL)

16:40 - 17:10 **Café**

17:10 - 17:30 *Inverse methods to estimate synaptic conductances with emphasis on non-smooth dynamical systems*
Catalina Vich (UIB)

17:30 - 17:50 *Attractors genesis in homoclinic bifurcation of three-dimensional diffeomorphisms*
Enrique Vigil (UNIOVI)

18:00 - 19:00 Reunión de la red

20:00 - 22:00 Cena

Viernes, 11 de noviembre

09:30 - 13:00 Sesión científica: Neurociencia
Responsable: Gemma Huguet (UPC)

09:30 - 10:30 *Playing with neurons: isolated and coupled*
Roberto Barrio (UNIZAR)

10:30 - 11:00 **Café**

11:00 - 12:00 *Mixed-Mode Oscillations in coupled multiple time scale piecewise linear oscillators. Application to a neuroendocrine system*
Soledad Fernández (US)

12:00 - 13:00 *Synchronization in firing rate models with synaptic delays*
Ernest Montbrió (UPF)

13:00 - 15:00 Almuerzo

ABSTRACTS

(por orden alfabético del primer autor)

Playing with neurons: isolated and coupled

R. Barrio, S. Ibáñez, A. Lozano-Rojo, M. A. Martínez, L. Pérez, M. Rodríguez, S. Serrano

In this talk we present some applications from mathematical neuroscience with detailed biparametric "roadmaps" [1]. Such a roadmap provides an exhaustive information about the dynamics of a single neuron that one must have to build small neuron networks and to study rhythmogenesis in central pattern generators (CPG). In the first application we characterize the systematic changes in the topological structure of chaotic attractors that occur at spike-adding and homoclinic bifurcations in the slow-fast dynamics of neuron models [3, 7]. This phenomenon is detailed in the phenomenological Hindmarsh-Rose (HR) neuron model and a reduced model of the leech heart interneuron [2]. For the HR model we show that the unstable periodic orbits emerging through spike-adding bifurcations can be described by sequences of the symbolic encoding associated with its complex dynamics [3, 5]. The symbolic description allows us to understand the correlation between the bifurcations and the corresponding metamorphoses of the intrinsic structure of the chaotic attractor of the HR model.

In the second application, we reveal the existence of heteroclinic cycles between saddle fixed points (FP) and invariant circles (IC) in a 3-cell CPG network (leech heart neurons). Such a

cycle underlies a robust "jiggling" behavior in bursting synchronization. To study biologically plausible CPG models we employ novel techniques based on the Poincaré return maps for phase lags between coupled bursters [4]. Using the combination of these techniques we are able to aggregate big data to parametrically continue FPs and ICs of the maps and to fully disclose their bifurcation unfoldings as the network configuration is varied and how to control the different synchornization patterns [6]. Note that some of these synchronization patterns of individual neurons are related with some undesirable neurologic diseases, and they are believed to play a crucial role in the emergence of pathological rhythmic brain activity in different diseases, like Parkinson's disease.

References

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Variedades al borde de la ruptura hiperbólica

Florentino Borondo (Universidad Autónoma de Madrid)

En este seminario presetaremos brevemente las ideas quimicas que subyacen al concepto de estado de transición, ilustrandolas con diversos ejemplos de reacciones quimicas concretas. Asi mismo, se introduciran de una forma facil las correspondientes variedades invariantes que son relevantes en la Teoria del estado de Transicion.

Tesis: Monomial multisummability through Borel-Laplace transforms. Applications to singularly perturbed differential equations and Pfaffian systems

Sergio A. Carrillo (Universidad Sergio Arboleda)

Directores: Jorge Mozo Fernández (Universidad de Valladolid), David Blázquez Sanz (Universidad Nacional de Colombia, sede Medellín, Colombia)

La tesis se enmarca en el estudio de desarrollos asintóticos en dos variables, donde la variable principal está descrita por un monomio. La k-sumabilidad en un monomio, introducida por M. Canalis-Duran, J. Mozo y R. Schäfke resulta ser útil en el estudio de soluciones formales de sistemas de ecuaciones diferenciales ordinarias con coeficientes holomorfos singularmente

perturbados, que exhiben un punto singular irregular. Se demuestran dos resultados relevantes en el desarrollo de la teoría: la incompatibilidad de dos tales métodos de sumabilidad esencialmente distintos y la caracterización de la k-sumabilidad monomial a través de transformaciones integrales de tipo Borel-Laplace. Estas herramientas han permitido definir el concepto de multisumabilidad monomial para el caso de dos monomios y desarrollar sus principales propiedades. Los resultados se han aplicado a demostrar la sumabilidad monomial de soluciones formales de ciertas ecuaciones diferenciales parciales y al estudio de sistemas pfaffianos con cruzamientos normales en dos variables.

Constelaciones de satélites artificiales y posibles aplicaciones

Daniel Casanova Ortega (Centro Universitario de la Defensa Zaragoza, GME-IUMA – Universidad de Zaragoza)

Un conjunto de satélites artificiales trabajando de forma conjunta y persiguiendo un objetivo común recibe el nombre de constelación de satélites. En muchas ocasiones, las misiones espaciales precisan de ellas en lugar de un único satélite artificial. Se presentarán diferentes formas de diseñar una constelación de satélites, centrándonos en las denominadas "Flower constellations". Además, se introducirán las "Time Constellations", un tipo de constelaciones que permiten distribuir los satélites artificiales en su órbita relativa facilitando la inclusión de perturbaciones orbitales. Finalmente, mostraremos diferentes aplicaciones de este tipo de constelaciones.

Global flow of the Parabolic Restricted Three-Body Problem

Josep M. Cors (Universitat Politècnica de Catalunya)

A close approach of two galaxies cause significant modification of the mass distribution. Focussing just on one particle that initially stays in one galaxy, after the close encounter, it can jump to the other galaxy or escape.
Taking this very simple model in mind, we consider in this talk the so called Planar Parabolic Restricted Three-Body Problem, which describes the motion of a massless particle submitted to the gravitational attraction of two masses -called primaries- (two galaxies) that move in parabolic orbits around their common center of mass, when the primaries and the particle move in the same plane.
The system is gradient-like and has exactly ten hyperbolic equilibrium points lying on the boundary manifolds corresponding to escape of the primaries in past and future time. The global flow of the system is described in terms of the final evolution (forwards and backwards in time) of the solutions. We will see the invariant manifolds of the equilibrium points play a key role in the dynamics.
Finally, we study numerically the connections between the invariant manifolds associated to the equilibrium points, paying special attention to capture and escape orbits. After a close encounter the resulting dynamics copy very well the bridges and tails seen in some multiple galaxies.
Results are obtained in collaboration with E. Barrabés, L. Garcia and M. Ollé.

Dynamics of a particle in some cases of the N-body problem

Antonio Elipe (Universidad de Zaragoza)

The restriced three-body problem is the most widely studied problem in Celestial Mechanics. In the last three decades this problem has been extended by considering other forces apart from the gravitation, like radiation pressure or by considering some of the primaries has finite dimensions. The dynamics of these extended problems is very isteresting, since there are new parameters. Again, this problem is extenden by considering three or more primaries, or by considering a central body with a ring. In the communication we will describe the problem, and present some results on bifurcations and periodic orbits.

Tesis: Local uniformization of codimension one foliations. Rational archimedean valuations

Miguel Fernández Duque (Universidad de Valladolid)

Director: Felipe Cano (Universidad de Valladolid)

La reducción de singularidades de foliaciones de codimensión uno es conocida en el caso de espacios ambiente de dimensión dos (Seidenberg 1968) y tres (Cano 2004). Sin embargo en dimensión mayor no tenemos resultados globales. Siguiendo las ideas de Zariski en este trabajo obtenemos uniformización local para foliaciones de codimensión uno en dimensión ambiente arbitraria en el caso de valoraciones arquimedianas racionales.

Mixed-Mode Oscillations in coupled multiple time scale piecewise linear oscillators. Application to a neuroendocrine system

S. Fernández-García (Dpto. EDAN, Universidad de Sevilla), M. Desroches, M. Krupa (MathNeuro, Inria Sophia Antipolis Méditerranée) and F. Clément (Mycenae, Inria Paris)

The main assumption underlying conductance-based neuron models is that a neuron behaves as an electronic circuit, which has been successfully modeled by Piecewise linear (PWL) systems. In [1], a four dimensional system was constructed and analyzed modeling the pulse and surge pattern of gonadotropin releasing hormone secretion by hypothalamic neurons in female mammals. The model consists of two coupled FitzHugh-Nagumo (FHN) systems (a simplified planar version of the celebrated Hodgkin-Huxley model) running on different time scales. In the first work that we present here [2], we have replaced the FHN subsystems by two PWL equivalent, namely McKean caricatures, where the original cubic function is replaced by a PWL function that preserves the cubic shape. This change allows us to keep the richness of the dynamics with better access to quantitative outputs. Finally, we present an extension of the PWL model [3], accounting for Mixed Mode oscillations appearing in the smooth original model [4]. We focus on interacting canard phenomena [5] underlying changes and exchanges in oscillations number.

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Variedades al borde de la ruptura hiperbólica

Alex Haro (Universitat de Barcelona)

El comportamiento a largo plazo de un sistema dinámico está gobernado por sus objetos invariantes. Es por tanto muy importante entender qué objetos persisten bajo perturbaciones de un sistema, y cuáles son sus mecanismos de rotura. Es bien conocido que la variedades invariantes que son persistentes bajo pequeñas perturbaciones son las variedades normalmente hiperbólicas. En esta presentación consideraremos diversos ejemplos de mecanismos de destrucción de variedades normalmente hiperbólicas. Los resultados han sido realizados en cola-

boración con Marta Canadell, Jordi-Lluís Figueras y Rafael de la Llave.

Teoría variacional del Estado de Transición: Fundamentos y aplicaciones a las reacciones químicas y bioquímicas

José M. Lluch (Universitat Autònoma de Barcelona)

La Teoría del Estado de Transición es probablemente la teoría más útil y más extendida de la Química. En esta exposición se presentan los prerrequisitos y fundamentos de la misma utilizando su formulación dinámica, y se comparan la teoría Convencional con la teoría Variacional. Se discute la dependencia de la presión para reacciones en fase gas y se presenta la Ecuación Máster. A continuación se explican los diferentes pasos sucesivos que hay que realizar para el cálculo de la constante de velocidad de una reacción química. Finalmente se explica cómo se aplica la Teoría Variacional del Estado de Transición a reacciones enzimáticas que incluyen decenas de miles de átomos.

Synchronization patterns in firing rate models with synaptic delay

Ernest Montbrió (Universitat Pompeu Fabra)

Collective chaos is shown to emerge, via a period-doubling cascade, from quasiperiodic partial synchronization in a population of identical inhibitory neurons with delayed global coupling. This system is thoroughly investigated by means of an exact model of the macroscopic firing rate dynamics, valid in the thermodynamic limit. The collective chaotic state is reproduced numerically with a finite population, and persists in the

presence of weak heterogeneities. Finally, the relationship of the model's dynamics with fast neuronal oscillations is discussed.

Estados de transición y variedades invariantes

Fabio Revuelta (Universidad Politécnica de Madrid e ICMAT)

El cálculo de la velocidad de reacción de un sistema químico por medio de simulaciones numéricas puede resultar extraordinariamente costoso debido al elevado número de partículas necesarias para simular el baño que lo rodea, que es del orden del número de Avogadro (1023), por lo que la utilización de ciertas aproximaciones resulta indispensable. Una de las más fructíferas es la teoría del estado de transición. Esta teoría se centra en el estudio del llamado "complejo activado" o "estado de transición", que actúa como un cuello de botella para la reactividad. El complejo activado es un estado tremendamente inestable en el que el sistema no está en el estado de partida ("reactivos") ni en el estado final ("productos"), sino en una configuración intermedia.
A lo largo de los últimos años se ha comenzado a analizar la geometría del estado de transición aplicando métodos de la mecánica celeste para describir mejor cuál es el mecanismo de reacción. En esta charla repasaremos cómo se pueden emplear ciertas estructuras geométricas -las variedades invariantes- para (i) identificar las trayectorias reactivas y (ii) calcular velocidades de reacción en sistemas en fase condensada.

Tesis: Analytical tools to study the criticality at the outer boundary of potential centers

David Rojas (Universitat Autònoma de Barcelona)

Directores: Francesc Mañosas (Universitat Autònoma de Barcelona), Jordi Villadelprat (Universitat Rovira i Virgili)

The main interest of this PhD dissertation is contained in the framework of the qualitative theory of differential equations. Our objects of study are families of systems of centers in the plane. We introduce the notions of critical periodic orbit and criticality, which are the counterparts of the notions of limit cycle and cyclicity in the framework of the Hilbert's sixteenth problem, respectively.

Our main interest is to study the bifurcation of critical periodic orbits from the outer boundary of the period annulus. According with the notion of criticality, we shall study the number of critical periodic orbits of a continuous center that can emerge or disappear from the outer boundary of the period annulus as we move slightly the parameter. More concretely, we are concerned with continuous families of planar analytic potential systems that have a non-degenerated center at the origin. The tools we develop allow to tackle the problem in the following two situations: either the energy at the outer boundary is infinite or finite for all the parameters. In these situations, we give sufficient conditions in order that the criticality at the outer boundary of the period annulus is less or equal than n. The main idea in both cases is to find some analytic functions verifying that we can embed the derivative of the period function into an ECT-system. This implies in particular that the derivative of the period function has at most n zeros near the energy at the outer boundary and, accordingly, the criticality is bounded by n. Our testing ground in this work is the

two-parametric family of potential differential systems given by $\dot{x} = -y, \dot{y} = (1+x)^p - (1+x)^q$. The period function associated to the system above was previously studied by Miyamoto and Yagasaki, who prove that the period function is monotonous when $q = 1$ and $p > 1$. We improve this result together with some other results concerning the bifurcation of critical periodic orbits from the center, from the interior when we perturb isochronous centers, and from the outer boundary of the period annulus. The combination of all these results will lead us to propose a conjectural bifurcation diagram for the global behaviour of the period function of the system under consideration.

Tesis: Numerical Computation of Invariant Objects with Wavelets

David Romero (Universitat Autònoma de Barcelona)

Director: Lluís Alsedà (Universitat Autònoma de Barcelona)

In certain classes of Dynamical Systems invariant sets with a strange geometry appear. For example, under certain conditions, the iteration of two-dimensional quasi-periodically forced skew product gives us Strange Non-Chaotic Attractors, φ.
To obtain analytical approximation of these objects it seems more natural to use wavelets instead of the more usual Fourier approach due to its adaptability. The aim of this thesis is to describe an efficient algorithm for the semi-analytical computation of the invariant object, using both Daubechies and Haar wavelets, by means of the numerical computation of the wavelet coefficients, namely $\mathrm{D}^{\mathrm{PER}}$.
The aim for this exercise is twofold. From one side to be able to study possible bifurcations or zoom in the "pinching zone" of

the object. From the other side try to get estimates of the regularity of the object. The study of this regularity depending on parameters, for a certain models of skew products, may give another point of view to the fractalization routes described in the literature and that are currently under discussion.
To perform such exercise(s), firstly, we have translated the $\mathbb{R}$-Daubechies wavelets language to $\mathbb{S}^1$. After that, we have carried out two different strategies to get the wavelet coefficients D^{PER}. The first one based on the Fast Wavelet Transform. The other, solve the Invariance Equation using the Newton's method and iterative solvers (specially preconditioning techniques based on wavelets). From such coefficients D^{PER} we get (numerical) estimations for the aforesaid proposed questions.

Tesis: A precession model explaining warped galaxies

Patricia Sanchez-Martin (Universidad Ramon Llull)

Directores: Josep J. Masdemont Soler (Universitat Politècnica de Catalunya), Mercè Romero Gómez (Universitat de Barcelona)

Hubble's "tuning-fork" diagram classifies galaxies into a reduced set of types, according to their morphology and components. In the case of barred galaxies, previous planar models given by J. Masdemont and M. Romero-Gómez explain their ring and spiral shape by means of invariant manifolds.

Now, working with a three dimensional model, we show why the majority of these barred galaxies are warped, a phenomenon that has been widely observed, but for which up to date no theory could account for all of its characteristics. The warped

shape consists in a integral-sign form when the galaxies are seen from an edge-on point of view. We start from the fact that the formation of the bar produces a small misalignment between the angular momentum of the galaxy and its angular velocity, giving rise to a precession of its main morphological components. We work with the resulting model in a precessing reference system, selected in such a way to make the angular momentum and angular velocity of the body time independent.

Our precession model is persistent in time. The warped shape is reached by the invariant manifolds of the unstable periodic orbits departing from the equilibrium points at the ends of the bar. These manifolds constitute the arms and rings of barred galaxies, being their skeleton. Looking at them from an edge-on viewpoint, we find that these manifolds present warped shapes such as those recognized in observations of warped galaxies, with a close concordance in angles.

Finally, we present preliminary work on a non-autonomous precession model with a time depending pattern speed for the bar. This model has been studied by means of Lagrangian Coherent Structures. We have found that these structures play an analogous role as invariant manifolds in autonomous models.

Tesis: Inverse Methods to estimate synaptic conductances with emphasis on non-smooth dynamical systems

Catalina Vich (Universitat de les Illes Balears)

Directores: Rafel Prohens (Universitat de les Illes Balears) y Toni Gillamon (Universitat Politècnica de Catalunya)

This thesis aims at contributing in the scientific fields of mathematical and computational neuroscience and dynamical systems. The main problem we address is the estimation of the time-course of synaptic conductances impinging on a neuron, that is, the quantity of information that a single neuron is receiving, a relevant aspect when trying to unveil brain's connectivity.

However, the time course of synaptic conductances cannot be extracted in a direct way from experiments and, therefore, inverse methods to estimate them from feasible recordings (like the neuron's membrane potential) become necessary. All the approaches provided in the literature, both experimental and theoretical, present some main shortcomings: (a) wrong assumptions of linear relationships between input current and output voltage; and, (b) the need of using more than one recording, thus forcing to assume the same functional connectivity in two different experiments. Thus, it becomes a non-trivial challenge for neuroscience.

In this thesis, we tackle this estimation problem by using minimal models of single cell dynamics and studying them by means of different techniques for slow-fast dynamics, stochastic differential equations and non-smooth models. We see that miss estimations derived from nonlinear effects in the spiking regime are also present in the sub-threshold when ionic currents are active in this regime. Consequently, we provide new methods to improve the estimations of synaptic conductances in this situation. Finally, we also provide a proof-of-concept of a general deterministic approach to deal with estimations in spiking regimes, when the neuron present an oscillatory behaviour.

The results are complemented with two immersions on two formative aspects within the scientific framework described above: (1) a theoretical/analytical study of slow-fast n-dimensional piecewise linear differential systems, where we prove a Fenichel's like Theorem and the existence and location of maximal canards; (2) the implementation of a complex neuronal network describing up/down states observed in the visual cortex, which we also use as a benchmark to obtain realistic synaptic conductance profiles for different cell types and diverse plasticity conditions in the network.

Tesis: Attractors genesis in homoclinic bifurcation of three-dimensional diffeomorphisms

Enrique Vigil (Investigador postdoctoral en CMUP, Portugal)

Director: Antonio Pumariño (Universidad de Oviedo)

Es conocido que si una familia uniparamétrica de difeomorfismos bidimensionales despliega una tangencia homoclínica, es posible construir una familia de aplicaciones límite retorno asociada que resulta ser muy cercana a la familia cuadrática unidimensional $f_a(x) = 1 - ax^2$.
En [2], el autor define la familia de aplicaciones límite retorno $T_{a,b}(x, y) = (a + y^2; x + by)$ asociada a familias de difeomorfismos tridimensionales que despliegan tangencias homoclínicas. En [3], los autores realizan un exhaustivo análisis numérico de la familia $T_{a,b}$ que muestra la (posible) existencia de atractores extraños con uno y dos exponentes de Lyapunov. Con el objetivo de demostrar que dichos atractores extraños realmente existen, se han construido ciertas aplicaciones bidimensionales y lineales a trozos, llamadas Expanding Baker Maps (EBMs),

que exhiben los mismos tipos de atractores observados para la familia $T_{a,b}$. El objetivo de la tesis, es explicar el origen de las EBMs y su conexión con las aplicaciones $T_{a,b}$. Además, se demuestra que las EBMs presentan atractores extraños con una única medida ergódica, continua, invariante y absolutamente continua (esta parte se incluye en [4] y [5]) y que nuestra familia de aplicaciones es estadísticamente estable (véase [1]).

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