BMD 2014
Barcelona Mathematical Days

Congrés de la Societat Catalana de Matemàtiques

Institut d'Estudis Catalans

Barcelona

7–8 November 2014

Schedule and Abstracts

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General Schedule

General Schedule

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10:30 – 11:00	**Coffee break**	
11:00 – 13:00	**Thematic sessions:**	
	Across Arithmetic	Sala Prat de la Riba
	Mathematics in Life Sciences	Sala Pere Coromines
	Random Discrete Structures	Sala Nicolau d'Olwer
15:00 – 16:00	**Plenary talk:** Javier Fernández de Bobadilla	Sala Prat de la Riba
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16:30 – 19:00	**Thematic sessions:**	
	Geometric Analysis and Related Topics	Sala Pere Coromines
	Geometric Structures in Interaction	Sala Nicolau d'Olwer
	New Directions in Nonsmooth Dynamics	Sala Prat de la Riba
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	Geometric Analysis and Related Topics	Sala Pere Coromines
	Geometric Structures in Interaction	Sala Nicolau d'Olwer
	New Directions in Nonsmooth Dynamics	Sala Prat de la Riba
15:00 – 16:00	**Plenary talk:** Edriss S. Titi	Sala Prat de la Riba
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	Across Arithmetic	Sala Prat de la Riba
	Mathematics in Life Sciences	Sala Pere Coromines
	Random Discrete Structures	Sala Nicolau d'Olwer

Plenary Lectures

Schedule

Friday 9:30 – 10:30, Sala Prat de la Riba

Günter M. Ziegler (Freie Universität Berlin)

The story of $3N$ points in a plane

Friday 15:00 – 16:00, Sala Prat de la Riba

Javier Fernández de Bobadilla (ICMAT, Madrid, and Institute for Advanced Study, Princeton)

Birational geometry and arc spaces

Saturday 9:30 – 10:30, Sala Prat de la Riba

Stéphane Mallat (École Normale Supérieure, Paris)

The mathematical curse of big data

Saturday 15:00 – 16:00, Sala Prat de la Riba

Edriss S. Titi (Weizmann Institute of Science, Rehovot, and University of California, Irvine)

The Navier–Stokes, Euler and other related equations

BIRATIONAL GEOMETRY AND ARC SPACES

JAVIER FERNÁNDEZ DE BOBADILLA
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Arc spaces were introduced by J. Nash in the 60's with the motivation of understanding the structure of resolution of singularities. They are spaces parametrising trajectories through singularities of algebraic varieties. He formulated a precise conjecture relating the structure of arc spaces with the birational geometry of singularities. Subsequently arc spaces were used extensively in algebraic geometry, both as the foundation of motivic integration (Kontsevich, Denef and Loeser) and as a tool to study invariants related with Mori's Minimal Model Programme (Mustata, Ein, Lazarsfeld, Ishii, de Fernex, and others).

In 2005 Ishii and Kollár found counterexamples to the Nash conjecture in dimensions 4 and higher. In 2011 Pe Pereira and myself proved the Nash conjecture for surfaces, and in 2012 de Fernex and Kollár found counterexamples in dimension 3. Despite these counterexamples it was understood that the Nash conjecture should have a revised formulation in dimension higher than 2, and that this formulation had to do with Mori's programme for birational classification of higher dimensional algebraic varieties. In 2014 de Fernex and Docampo made a huge step forward towards the understanding of the Nash conjecture in terms of the Minimal Model Programme.

In this talk I will explain to a general mathematical audience the content of the Nash conjecture and how it relates with birational geometry and Mori's programme, and will survey the advances described above and what is still left to be done.

THE MATHEMATICAL CURSE OF BIG DATA

STÉPHANE MALLAT

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The world is flooded by digital information, which records complex phenomena involving a large number of variables. Analyzing data amounts to approximate functions from sample values in high dimension. It faces a curse of dimensionality, because the space volume grows exponentially with the dimension. Avoiding this curse will lead us into a mathematical trip, which begins with statistics and probability and goes through functional approximation, harmonic analysis, high dimensional geometry, and group theory.

Despite this mathematical curse, learning algorithms have been considerably improved over the last 10 years, sometimes reaching a remarkable precision. These results are raising challenging mathematical questions which are fully open. Image and audio applications will illustrate the mathematics.

THE NAVIER–STOKES, EULER AND OTHER RELATED EQUATIONS

EDRISS S. TITI

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The University of California, Irvine

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In this talk I will survey the status of, and the most recent advances concerning, the questions of global regularity of solutions to the three-dimensional Navier–Stokes and Euler equations of incompressible fluids. Furthermore, and if time allows, I will also present recent global regularity (and finite time blow up) results concerning certain three-dimensional geophysical flows, including the three-dimensional viscous (non-viscous) "primitive equations" of oceanic and atmospheric dynamics.

THE STORY OF 3*N* POINTS IN A PLANE

GÜNTER M. ZIEGLER

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Nearly 60 years ago, the Cambridge undergraduate Bryan Birch showed that any "$3N$ points in a plane" can be split into N triples that span triangles with a non-empty intersection. He also conjectured a higher-dimensional version of this, which was proved by the young Norwegian mathematician Helge Tverberg (freezing, in a hotel room in Manchester) exactly fifty years ago.

This is the beginning of a remarkable story that I will try to survey in this lecture. Highlights include the discovery that "$3N$–2 points in a plane" would have been enough (and perhaps an even better starting point); the insight that this is really a problem of combinatorial topology; the "Topological Tverberg Theorem", proved by Bárány, Shlosman & Szücs for the case when N is a prime; a "colored version" of the problem proposed by Bárány & Larman in 1989, and finally proven in 2009 (joint with Blagojević and Matschke); and the 2014 discovery that from the Topological Tverberg Theorem one can get a lot of other results "nearly for free" (joint work with Pavle Blagojević and Florian Frick).

Thematic Session
Across Arithmetic

Organized by

Alan Lauder (University of Oxford) and Víctor Rotger (Universitat Politècnica de Catalunya)

Schedule

Friday 11:00 – 11:55, Sala Prat de la Riba

James Maynard (Université de Montréal and University of Oxford)

Small gaps between primes

Friday 12:05 – 13:00, Sala Prat de la Riba

Jennifer Balakrishnan (University of Oxford)

Coleman integration and integral points on hyperelliptic curves

Saturday 16:30 – 17:30, Sala Prat de la Riba

Jürgen Klüners (Universität Paderborn)

Constructive Galois theory

Saturday 17:45 – 18:45, Sala Prat de la Riba

Mladen Dimitrov (Université Lille 1)

The eigencurve at classical weight one points

COLEMAN INTEGRATION AND INTEGRAL POINTS ON HYPERELLIPTIC CURVES

JENNIFER BALAKRISHNAN

(in collaboration with A. Besser and S. Müller)

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We will discuss explicit computations of p-adic line integrals (Coleman integrals) on hyperelliptic curves and some applications. We will give examples of iterated Coleman integrals present in Kim's nonabelian Chabauty program. Moreover, we will discuss recent applications of using these integrals to find integral points on hyperelliptic curves. We use this to give a Chabauty-like method for computing p-adic approximations to integral points on such curves when the Mordell–Weil rank of the Jacobian equals the genus.

THE EIGENCURVE AT CLASSICAL WEIGHT ONE POINTS

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We determine the geometry of the p-adic eigencurve at points corresponding to classical modular forms of weight one, under a mild assumption of regularity at p, and give several number theoretic applications. Namely we prove that the eigencurve is always smooth at those points, and that it is étale over the weight space if and only if the form does not have real multiplication by a real quadratic field in which p splits. Our approach uses deformation theory of Galois representations and the Baker–Brumer theorem in transcendence theory.

CONSTRUCTIVE GALOIS THEORY

JÜRGEN KLÜNERS

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In constructive Galois theory, there are two main questions: the direct problem and the inverse problem. For the inverse problem the question is whether it is possible to find a polynomial such that the Galois group of that polynomial is a given finite group. In this talk, we will focus on the direct problem. Given a rational polynomial f, we explain how to compute the Galois group of this polynomial. The presented algorithms are implemented in Magma and work without any degree restriction. These methods apply over number fields and global function fields, too.

In a second part of the talk, we report on a database containing number fields up to degree 23. The database is complete in the sense that for each transitive group (with two exceptions) up to degree 23 there is at least one polynomial in the database which has this given Galois group. The database can be accessed via:
http://galoisdb.math.uni-paderborn.de

SMALL GAPS BETWEEN PRIMES

JAMES MAYNARD

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It is believed that there should be infinitely many pairs of primes which differ by 2; this is the famous twin prime conjecture. More generally, it is believed that for every positive integer m there should be infinitely many sets of m primes with each set contained in an interval of size roughly $m \log(m)$. Although proving these conjectures seems to be beyond our current techniques, recent progress has enabled us to obtain some partial results. We will introduce a refinement of the "GPY sieve method" for studying these problems. This refinement will allow us to show (amongst other things) that $\liminf_n (p_{n+m} - p_n) < \infty$ for any integer m, and so there are infinitely many bounded length intervals containing m primes. We will also discuss some extensions of this result.

Thematic Session

Geometric Analysis and Related Topics

Organized by

Pekka Koskela (Jyväskylän Yliopisto) and Xavier Tolsa (Universitat Autònoma de Barcelona)

Schedule

Friday 16:30 – 17:20, Sala Pere Coromines

Pekka Koskela (Jyväskylän Yliopisto)

A geometric characterization for planar Sobolev extension domains

Friday 17:30 – 17:55, Sala Pere Coromines

Albert Clop (Universitat Autònoma de Barcelona)

Nonlinear Beltrami equations and quasiconformal flows

Friday 18:00 – 18:50, Sala Pere Coromines

Carlos Pérez Moreno (Euskal Herriko Unibertsitatea and Ikerbasque)

Commutators of singular integrals with BMO functions

Saturday 11:00 – 11:50, Sala Pere Coromines

Joaquim Ortega-Cerdà (Universitat de Barcelona)

Marcinkiewicz–Zygmund inequalities in real algebraic varieties

Saturday 12:00 – 12:50, Sala Pere Coromines

Luigi Ambrosio (Scuola Normale Superiore di Pisa)

BMO-like seminorms and sets of finite perimeter

BMO-LIKE SEMINORMS AND SETS OF FINITE PERIMETER

LUIGI AMBROSIO
(in collaboration with J. Bourgain, H. Brezis and A. Figalli)
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In my lecture I will illustrate a recent work on the characterization of the perimeter and of sets of finite perimeter in terms of a BMO-like seminorm, solving positively a question raised in an earlier and recent work of H. Brezis, J. Bourgain and P. Mironescu. I will more generally compare this with other distributional and non-distributional criteria for the finiteness of perimeter.

NONLINEAR BELTRAMI EQUATIONS AND QUASICONFORMAL FLOWS

ALBERT CLOP

(in collaboration with K. Astala, D. Faraco, J. Jääskeläinen and L. Székelyhidi)

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It is well understood that every linear Beltrami equation in the plane admits a unique linear family of quasiconformal solutions. It was shown not that long ago that this also works conversely: every linear family of planar quasiconformal homeomorphisms uniquely determines a linear Beltrami equation. In this talk we will analyze a nonlinear counterpart to this correspondence.

A GEOMETRIC CHARACTERIZATION FOR PLANAR SOBOLEV EXTENSION DOMAINS

Pekka Koskela

(in collaboration with T. Rajala and Y. Zhang)

Jyväskylän Yliopisto

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We explain our recent results with Tapio Rajala and Yi Zhang that give a geometric characterization for those bounded simply-connected planar domains that admit an extension operator for the usual first-order Sobolev space of integrability degree p less than 2.

MARCINKIEWICZ–ZYGMUND INEQUALITIES IN REAL ALGEBRAIC VARIETIES

Joaquim Ortega-Cerdà
(in collaboration with R. Berman)
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I will present a joint work with Robert Berman where we consider the problem of sampling multivariate real polynomials of large degree in a general framework where the polynomials are defined on an affine real algebraic variety equipped with a weighted measure. It is shown that a necessary condition for sampling, in this general setting, is that the asymptotic density of sampling points is greater than the density of the corresponding weighted equilibrium measure, as defined in pluripotential theory. This result thus generalizes the well-known Landau-type results for sampling on the torus, where the corresponding critical density corresponds to the Nyqvist rate, as well as the classical result saying that zeroes of orthogonal polynomials become equidistributed with respect to the logarithmic equilibrium measure as the degree tends to infinity.

COMMUTATORS OF SINGULAR INTEGRALS WITH BMO FUNCTIONS

CARLOS PÉREZ MORENO

Euskal Herriko Unibertsitatea and Ikerbasque

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Commutators of singular integral operators with BMO functions were introduced in the seventies by Coifman–Rochberg and Weiss. These are very interesting operators for many reasons and their study became a classical topic in modern harmonic analysis. One reason of this interest is due to the fact that they are more singular than Calderón–Zygmund operators. This idea can be expressed in many ways. In this lecture we plan to give three reasons that explain this "bad" behavior. One of them is related to a sharp weighted L^2 estimate with respect to A_2 weights but the novelty is that the bound in terms of the A_2 constant of the weight is quadratic and no better while in the case of singular integrals it is simply linear. The second reason is the fact that there is an appropriate local sub-exponential decay which in the case of singular integrals is of exponential type instead. The third reason is related to the fact that commutators are controlled by iterations of the maximal function with a sharp new A_∞ constant.

Pieces of the lecture are part of joint works with D. Chung and C. Pereyra, with C. Ortiz and E. Rela, with T. Luque and E. Rela, and with T. Hytönen.

Thematic Session

Geometric Structures in Interaction

Organized by

Luis Álvarez-Cónsul (ICMAT) and Ignasi Mundet (Universitat de Barcelona)

Schedule

Friday 16:30 – 17:20, Sala Nicolau d'Olwer

Richard Wentworth (University of Maryland)

Deligne pairings and holomorphic extension of analytic torsion

Friday 17:30 – 18:20, Sala Nicolau d'Olwer

Eva Miranda (Universitat Politècnica de Catalunya, Barcelona)

Symplectic and Poisson structures with symmetries in interaction

Friday 18:30 – 19:00, Sala Nicolau d'Olwer

Mario García Fernández (ICMAT, Madrid)

Stability data, irregular connections and tropical curves

Saturday 11:00 – 11:30, Sala Nicolau d'Olwer

Pavel Safronov (University of Oxford)

Hamiltonian and quasi-Hamiltonian reduction via derived symplectic geometry

Saturday 11:35 – 12:05, Sala Nicolau d'Olwer

Tony Yue Yu (Université Paris Diderot)

Counting holomorphic discs via non-archimedean geometry

Saturday 12:10 – 13:00, Sala Nicolau d'Olwer

Ludmil Katzarkov (Universität Wien)

Stability structures and Hitchin systems

STABILITY DATA, IRREGULAR CONNECTIONS AND TROPICAL CURVES

MARIO GARCÍA FERNÁNDEZ

(in collaboration with S. Filippini and J. Stoppa)

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We construct isomonodromic families of irregular meromorphic connections on $\mathbf{P}^1$, with values in the derivations of a class of infinite-dimensional Poisson algebras. Our main results concern the limits of the families as we vary a scaling parameter R. In the $R \to 0$ "conformal limit" we recover a semi-classical version of the connections introduced by Bridgeland and Toledano Laredo (and so the Joyce holomorphic generating functions for DT invariants). In the $R \to \infty$ "large complex structure limit" the families relate to tropical curves in the plane and tropical/GW invariants. The connections we construct are a rough but rigorous approximation to the (mostly conjectural) four-dimensional tt^*-connections introduced by Gaiotto–Moore–Neitzke.

STABILITY STRUCTURES AND HITCHIN SYSTEMS

LUDMIL KATZARKOV
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In this talk we will introduce a new Hodge type of structure and look from its perspective to some classical examples.

SYMPLECTIC AND POISSON STRUCTURES WITH SYMMETRIES IN INTERACTION

EVA MIRANDA

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Hamiltonian actions constitute a central object of study in symplectic geometry. Special attention has been devoted to the toric case. Toric symplectic manifolds provide natural examples of integrable systems and every integrable system on a symplectic manifold is a toric manifold in a neighbourhood of a compact fiber (Arnold–Liouville). The classification of toric symplectic manifolds is given by Delzant's theorem in terms of the image of the moment map (Delzant polytope).

The goal of this talk is to present a comprehensive tour through different results concerning Hamiltonian group actions on Poisson manifolds (a generalization of symplectic manifolds) with an emphasis on the classification problems and the study of their rigidity.

We will first consider a simple class of Poisson manifolds which is close to the symplectic realm (b-symplectic manifolds) and sketch a proof of a Delzant theorem for toric b-symplectic manifolds taking as starting point the case of surfaces. These Poisson manifolds can be seen as symplectic manifolds with singularities and admit an adaptation of Moser's path method from symplectic geometry.

Time permitting, we will end up this talk with a rigidity theorem for Hamiltonian group actions on Poisson manifolds. The tools needed to consider general Poisson manifolds require a generalization of Nash–Moser's techniques native to geometric analysis.

HAMILTONIAN AND QUASI-HAMILTONIAN REDUCTION VIA DERIVED SYMPLECTIC GEOMETRY

PAVEL SAFRONOV
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I will explain an approach to Hamiltonian reduction using derived symplectic geometry. Roughly speaking, the reduced space can be presented as an intersection of two Lagrangians in a shifted symplectic space, which therefore carries a natural symplectic structure. A slight modification of the construction gives rise to quasi-Hamiltonian reduction. In the end I will mention how quasi-Hamiltonian reduction naturally fits into a classical topological field theory called classical Chern–Simons theory.

DELIGNE PAIRINGS AND HOLOMORPHIC EXTENSION OF ANALYTIC TORSION

RICHARD WENTWORTH

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The purpose of this talk is to suggest an approach to certain constructions in hyperkähler geometry via Deligne pairings. I will discuss the concrete example of rank 1 Higgs bundles on a Riemann surface. The method produces a flat connection on a combination of determinant bundles over the de Rham moduli space. We show that the holomorphic extension of analytic torsion, introduced by Fay and used in this context by Hitchin, can be interpreted as a covariantly constant section of this bundle. The hyperholomorphic line bundle on the twistor space admits a meromorphic connection, and this also easily follows from this construction.

COUNTING HOLOMORPHIC CYLINDERS VIA NON-ARCHIMEDEAN GEOMETRY

TONY YUE YU

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Counting the number of curves in an algebraic variety is a classical topic in algebraic geometry. Inspired by string theory and mirror symmetry, people started to look at not only closed curves, but also discs, cylinders, etc. In this talk, I will begin by presenting several beautiful historic results. Then I will explain how tropical geometry and non-archimedean analytic geometry enter the game of counting. If time permits, I will discuss a particular case of log Calabi–Yau surfaces, and explain its relations to the Kontsevich–Soibelman wall-crossing formula and the Gross–Siebert program.

Thematic Session

Mathematics in Life Sciences

Organized by

Tomás Alarcón (Centre de Recerca Matemàtica)
and Juan Soler (Universidad de Granada)

Schedule

Friday 11:00 – 11:40, Sala Pere Coromines

Esther Ibáñez-Marcelo (Centre de Recerca Matemàtica, Barcelona)

Evolutionary escape and surviving in populations with genotype-phenotype structure

Friday 11:40 – 12:20, Sala Pere Coromines

Daniel Sánchez-Taltavull (Centre de Recerca Matemàtica, Barcelona)

Stochastic dynamics of HIV-1 infection

Friday 12:20 – 13:00, Sala Pere Coromines

Pau Formosa-Jordan (University of Cambridge)

Unraveling salt-and-pepper patterning in the developing chick inner ear

Saturday 16:30 – 17:10, Sala Pere Coromines

Óscar Sánchez (Universidad de Granada)

Modelling through nonlinear flux-limited spreading

Saturday 17:10 – 17:50, Sala Pere Coromines

Rubén Pérez Carrasco (University College London)

Modelling of neural tube patterning

Saturday 17:50 – 18:30, Sala Pere Coromines

Marta Ibañes (Universitat de Barcelona)

Auxin hormonal transport in plants: Balance between entry and exit

Saturday 18:30 – 19:10, Sala Pere Coromines

Aurora Hernández-Machado (Universitat de Barcelona)

Tumor angiogenesis and vascular patterning: A mathematical model

UNRAVELING SALT-AND-PEPPER PATTERNING IN THE DEVELOPING CHICK INNER EAR

PAU FORMOSA-JORDAN

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During embryonic development, cells initially equivalent become distinct, differentiating into various kinds of cells in an orderly manner and creating spatial patterns. In different animal tissues, patterning arises from the direct interaction between adjacent cells. This interaction occurs through the binding of two different proteins belonging to the Notch signalling pathway, the Notch receptor and its ligand, each anchored in the cell membrane of adjacent cells. It is well known that this cell-to-cell interaction enables the creation of a positive intercellular feedback that drives fine-grained patterning of two different cell types. In the last few years, mathematical modelling has been fundamental for understanding how Notch signalling drives patterning. In this talk I will present our new theoretical and experimental results for studying how Notch signalling drives patterning in the chick inner ear. In this tissue, it has been proposed that the Notch-mediated positive feedback loop first acts as an intercellular mutual activatory circuit, and afterwards it switches to a mutual inhibitory circuit, but how this transition occurs remains elusive. Our study reveals that competition and optimality effects in the Notch signalling pathway are essential for the proper transition from mutual activation to mutual inhibition circuits. Moreover, our results sustain that an extra intracellular positive feedback loop in the network provides a striking robustness to the formed pattern.

TUMOR ANGIOGENESIS AND VASCULAR PATTERNING: A MATHEMATICAL MODEL

AURORA HERNÁNDEZ-MACHADO

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Tumor angiogenesis is a challenging problem with important consequences for diagnosis and treatment of cancer. Angiogenesis is the process by which new blood vessels grow from existing ones. The idea that a successful establishment of a solid tumor depends on neovascularization has given rise to therapies to deprive the tumor from oxygen and nutrients. However, an optimal therapy requires high resolution imaging to detect the vessels and advanced mathematical models to predict the vascular patterning. In this talk, I will present a multi-scale mathematical model that combines the benefits of a continuous description based on a phase-field model and the capability of tracking individual tip cells.

EVOLUTIONARY ESCAPE AND SURVIVING IN POPULATIONS WITH GENOTYPE-PHENOTYPE STRUCTURE

ESTHER IBÁÑEZ-MARCELO

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We study the problem of evolutionary escape and survival for cell populations with genotype-phenotype map. Classical approaches, which do not consider populations with genotype-phenotype structure, have focused on the problem of estimating the probability of reaching a well-adapted (so-called *escape*) genotype from an ill-adapted one. This perspective implies that, once the escape genotype has been reached, the population survives with probability one. If genotype-phenotype structure is added to the picture, the situation is not quite so simple: genotype-phenotype structure provides a complex structure to the escape phenotype which, in particular, endows robustness to the escape phenotype, so that the dynamics of the system post-escape is not trivial. Furthermore, the consideration of genotype-phenotype map introduces a complex topology in the genotype-phenotype network. In order to explore these issues, we formulate a population dynamics model, consisting of a multi-type time-continuous branching process, where types are associated to genotypes and their birth and death probabilities depend on the associated phenotype (non-escape or escape). We show that, within the setting associated to the escape problem, separation of time scales naturally arises and two dynamical regimes emerge: a fast-decaying regime associated to the escape process itself, and a slow regime which corresponds to the (survival) dynamics of the population once the escape phenotype has been reached (i.e., conditioned to escape). We exploit this separation of time scales to analyse the topological factors which determine escape and survival. In particular, the aim of this work is to analyse the influence of topological properties associated to robustness and evolvability on the probability of escape and on the probability of survival upon escape. We show that, while the escape probability depends on the size of the neutral network of the escape phenotype (i.e., its degree), the probability of survival is essentially determined by its robustness (i.e., the resilience of the escape phenotype against genetic mutations), measured in terms of a weighted clustering coefficient.

AUXIN HORMONAL TRANSPORT IN PLANTS: BALANCE BETWEEN ENTRY AND EXIT

MARTA IBAÑES

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The conducting tissues of the plant, which transport water and nutrients, are spatially organized forming patterns. A cross section of the shoot of plant model organism *Arabidopsis thaliana* reveals a periodic pattern of these conducting tissues. We make use of a mathematical model to describe relevant features of this pattern and provide experimental evidence to support it. The model describes a mechanism for pattern formation that has been recurrently found in plants. This mechanism drives spontaneous symmetry breaking within cells and concomitantly at the tissue level through the transport of a hormone named auxin. Our results characterize novel aspects of this mechanism.

MODELLING OF NEURAL TUBE PATTERNING

RUBÉN PÉREZ CARRASCO

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During embryo development, cellular tissues made of homogeneous identical cells are able to differentiate autonomously giving place to more specific cell types. As a result, an accurate spatial distribution of cell types arise despite the highly non-linear and noisy nature of the system at different scales, from a tissular scale to a molecular scale.

At a large scale, cells interact between them creating a tissue. These interactions are characterised by individual behaviour of the cell such as cell division, apoptosis or interkinetic nuclear movement. Additionally, each individual cell will react to gradients of morphogens (externally secreted signals), that will give each cell positional information in the tissue, and a continuous morphogen gradient along the tissue interacts with the genetic expression of each cell giving place to discrete sets of well and sharp patterns of gene expression. At a cellular level, this regulation process occurs by the genetic interaction between different proteins of the system, so-called *genetic regulation networks*. Finally, at a molecular level, the regulation and expression of each protein involves different reactions that provide variate genetic dynamical response.

One example of developmental tissue is the neural tube, which gives place to the different neurons forming the central nervous system of vertebrates. In this talk we will review the challenges that involve understanding the patterning of the neural tube at different scales and the tools used to solve them. These tools include the use of vertex models in order to model the tissue, the dynamical analysis of the ODEs describing the interaction between a morphogen and a genetic regulatory network, and the role of noise in the genetic expression.

MODELLING THROUGH NONLINEAR FLUX-LIMITED SPREADING

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Reaction-diffusion equations are nowadays a basic tool in the modelling of populations whose dynamic is basically ruled by two processes: local reactions, in which the populations interact between themselves, and diffusion, which makes the populations spread out in the physical space. In the ambient of the embryonic morphogenesis (see [1]), it has been proposed the adaptation of the classical linear diffusion mechanism (Fick's Law) by considering flux-limited operators. The employment of limited diffusion ideas in biological ambients provokes new mathematical questions concerning pattern formation or even qualitative behavior. This talk is devoted to present recent advances in the analysis of traveling waves to some flux-limited reaction-diffusion models where the classical traveling wave profiles will coexists with discontinuous waves spreading through the medium with finite speed (see [2, 3]).

References

[1] M. Verbeni, O. Sánchez, E. Mollica, I. Siegl-Cachedenier, A. Carlenton, I. Guerrero, A. Ruiz i Altaba, J. Soler, *Morphogenetic action through flux-limited spreading*, Physics of Life Reviews **10** (2013), 457–475.

[2] J. Campos, P. Guerrero, O. Sánchez, J. Soler, *On the analysis of traveling waves to a nonlinear flux limited reaction-diffusion equation*, Ann. Inst. H. Poincaré Anal. Non Linéaire **30 (1)** (2013), 141–155.

[3] J. Calvo, J. Campos, V. Caselles, O. Sánchez, J. Soler, *Pattern formation in a flux limited reaction-diffusion equation of porous media type*, preprint.

STOCHASTIC DYNAMICS OF HIV-1 INFECTION

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HIV-1 infected patients are effectively treated with highly active anti-retroviral therapy (HAART). Although HAART forces the viral load to decay below the standard detection limits (e.g., 50 RNA copies/ml), the therapies are unable to suppress completely the virus, and the infection persists in form of a small latent reservoir. One of the evidences of the persistence of the infection are the so-called viral blips, that is, transient episodes of viremia above the detection limit. The emergence mechanisms of these blips are unknown. In this talk we explore the different models that one can find in the literature to explain the dynamics of the infection under anti-retroviral therapy.

Recent research activity has been focused on formulating strategies aimed at removing the latent infection. One such proposal consists on an antigen-stimulation to elevate the rate of activation of the latently infected cells. In this talk we include in one of the models the antigen-stimulation therapy, to study how the life-time of the infection depends on the activation rate of the latently infected cells and possible side-effects.

Thematic Session

New Directions in Nonsmooth Dynamics

Organized by

Amadeu Delshams (Universitat Politècnica de Catalunya) and Mike R. Jeffrey (University of Bristol)

Schedule

Friday 16:30 – 17:30, Sala Prat de la Riba

Martin Homer (Department of Engineering Mathematics, University of Bristol)

Filippov unplugged

Friday 17:30 – 18:00, Sala Prat de la Riba

Ernst Hairer (Université de Genève)

Stabilization of the hidden dynamics in discontinuous differential equations

Friday 18:00 – 18:30, Sala Prat de la Riba

Tere M. Seara (Universitat Politècnica de Catalunya, Barcelona)

Sliding bifurcations after Sotomayor–Teixeira regularization: an application of singular perturbation theory to Filippov systems.

Friday 18:30 – 19:00, Sala Prat de la Riba

Enric Fossas (Universitat Politècnica de Catalunya, Barcelona)

A coupled inductor boost converter as a piecewise linear complementarity system: model and feedback control

Saturday 11:00 – 11:30, Sala Prat de la Riba

Paul Glendinning (University of Manchester)

From low to high dimensional piecewise smooth systems

Saturday 11:30 – 12:00, Sala Prat de la Riba

Piotr Kowalczyk (Manchester Metropolitan University)

Complexity and dynamics of switched human balance control systems with noise

Saturday 12:00 – 12:30, Sala Prat de la Riba

Enrique Ponce (Universidad de Sevilla)

Exploiting the features of a linear boundary focus in getting limit cycles

Saturday 12:30 – 13:00, Sala Prat de la Riba

Josep M. Olm (Universitat Politècnica de Catalunya, Barcelona)

On Abel differential equations of the 2nd kind and exact inversion with boost DC-AC converters

A COUPLED INDUCTOR BOOST CONVERTER AS A PIECEWISE LINEAR COMPLEMENTARITY SYSTEM: MODEL AND FEEDBACK CONTROL

ENRIC FOSSAS

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The aim of the talk is to present the problems arising when analysing piecewise continuous systems in the frame of feedback systems. For design purposes it is important to have tools that allow to determine the behaviour of the system when the loop is closed. In the present case a control system with a switch and two diodes will be shown. It will be modelled and analysed as a piecewise complementary system.

FROM LOW TO HIGH DIMENSIONAL PIECEWISE SMOOTH SYSTEMS

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There are some aspects of the bifurcations of piecewise smooth dynamics that are similar to their smooth counterparts, and others that are very different. I will describe a number of problems ranging from simple one-dimensional maps to n-dimensional normal forms, emphasising how the piecewise smooth case can be radically different from its smooth counterpart.

STABILIZATION OF THE HIDDEN DYNAMICS IN DISCONTINUOUS DIFFERENTIAL EQUATIONS

ERNST HAIRER

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This talk considers ordinary differential equations with discontinuous right-hand side, where the discontinuity of the vector field takes place on smooth surfaces of the phase space. The main emphasis is put on what happens in the intersection of two of these surfaces. To avoid the ambiguity of the Filippov approach, bilinear convex combinations of the adjacent vector fields are considered.

The hidden dynamics is given by a two-dimensional dynamical system (in the case of codimension-2 sliding modes) and describes the smooth transition of solution directions, which occurs instantaneously in the jump discontinuity of vector fields. This talk studies solutions of the hidden dynamics and, in particular, the stability of stationary points which correspond to codimension-2 sliding modes.

Close to the intersection of discontinuity surfaces, the hidden dynamics is realized by standard space regularizations. If a stationary point of the hidden dynamics is unstable, this results in high oscillations of frequency proportional to the inverse of the regularization parameter. A simple modification will be presented that permits to avoid this instability and makes the numerical treatment much more efficient.

FILIPPOV UNPLUGGED

MARTIN HOMER

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Almost every paper on nonsmooth systems references the book by Filippov *Differential Equations with Discontinuous Righthand Sides* (Kluwer, 1988). Yet it is a difficult read, with an obsolete section numbering system, few diagrams, dense text and very few examples. It is tempting to ask how many people have actually read it all, or know of the results that it contains. For the past 18 months or so, a group at the University of Bristol (the Bristol Filippov Group, BFG) has been systematically going through the text. Meeting for two hours once every week or so (with homework in between), we have endeavoured to understand all the material, and to extract those results that are relevant to the modern audience.

In this lecture, we will focus on a major result which does not appear to be widely known. This is Theorem 1 on p. 217 (originally due to Kozlova, itself a notoriously difficult paper to find), which gives necessary and sufficient conditions for a planar non smooth system of a certain class to be structurally stable in a closed bounded domain. To derive this result, we need, within the context of non smooth systems, to fundamentally revise our notions of 1) the solution to an equation, 2) singularities, 3) separatrices, 4) structural stability, and 5) topological equivalence.

This talk will not dwell on the fine detail of the many lemmas and corollaries needed to prove the theorem. Instead we will direct attention toward the importance of revising our understanding of notions well accepted in the smooth setting and the relevant sections of the book where that detail is contained. Several examples will be given to illustrate the talk.

COMPLEXITY AND DYNAMICS OF SWITCHED HUMAN BALANCE CONTROL SYSTEMS WITH NOISE

PIOTR KOWALCZYK

(in collaboration with S. Nema and I. Loram)

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Human neuromotor control system during quiet or perturbed standing, or object tracking, can be modelled by means of switched systems with noise, and time delay in the switching function. We link the dynamics of such systems with complexity measures such as Sample Entropy and Detrended Fluctuation Analyses. In particular, we seek to establish what is the effect of the presence of discontinuities on the complexity measures which we consider. We then link the results with complexity measures found in experimental data of human sway motion during quiet standing.

Finally, we analyse model-generated and experimental time series data sets in view of determining a pattern of control strategy triggered by the presence of intermittent control (switchings) by means of an algorithm that relies on the combination of wavelet analysis and normalised Hilbert transform. We obtain a time-frequency representation of a signal generated by our model system. We are then able to detect manifestations of discontinuities in the signal as spiking behaviour. We show that similar spikes can be detected by analysing experimental posturographic data sets.

ON ABEL DIFFERENTIAL EQUATIONS OF THE 2ND KIND AND EXACT INVERSION WITH BOOST DC-AC CONVERTERS

JOSEP M. OLM

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The use of DC-DC boost-based switched converter for DC-AC step-up inversion applications has been long handicapped by the fact that it requires non-offset, periodic current reference profiles that satisfy an Abel differential equation of the 2nd kind, and this is a challenging problem because the corresponding vector field becomes nonsmooth in zero-crossing points. As a consequence, the proposals made so far considered either offset inversion, which is much less interesting from a practical point of view, or theoretically unsupported approximate non-offset inversion schemes. However, sufficient conditions for the existence of periodic solutions with nonconstant sign in Abel equations of the 2nd kind have been recently reported. In this talk we review these results, and we apply them to the exact inversion problem with a boost DC-AC power converter.

EXPLOITING THE FEATURES OF A LINEAR BOUNDARY FOCUS IN GETTING LIMIT CYCLES

ENRIQUE PONCE

(in collaboration with E. Freire and F. Torres)

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Within the realm of planar piecewise smooth differential systems or Filippov systems, the appearance of a boundary focus under parameter variations can lead to a handful of bifurcations. We show how the special features of this singular point can be exploited to justify the existence of three limit cycles in planar Filippov systems whose discontinuous vector field is defined through two linear systems; see [1].

References

[1] E. Freire, E. Ponce and F. Torres, *A general mechanism to generate three limit cycles in planar Filippov systems with two zones*, Nonlinear Dynamics (2014) 78:251–263.

SLIDING BIFURCATIONS AFTER SOTOMAYOR–TEIXEIRA REGULARIZATION: AN APPLICATION OF SINGULAR PERTURBATION THEORY TO FILIPPOV SYSTEMS

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In this talk we do a detailed study, using geometric singular perturbation theory and matching asymptotic expansions, of the Sotomayor–Teixeira regularization of a Filippov system near a visible tangency. The main goal is to understand how global bifurcations involving sliding, which are typical for non-smooth systems, evolve to classical well-known bifurcations when the system is regularized.

We apply the local study to understand some global bifurcations of periodic orbits and homoclinic orbits. We take a one-parameter family of Filippov vector fields in the plane having a grazing-sliding bifurcation and we analyze the behavior in the corresponding regularized system. We relate the grazing sliding bifurcation of a repelling periodic orbit with the classical saddle node bifurcation. We also study a grazing homoclinic bifurcation.

Thematic Session

Random Discrete Structures

Organized by

Michael Drmota (Technische Universität Wien) and Oriol Serra (Universitat Politècnica de Catalunya)

Schedule

Friday 11:00 – 11:30, Sala Nicolau d'Olwer

Benjamin Sudakov (ETH Zürich)

Cycle packing

Friday 11:40 – 12:10, Sala Nicolau d'Olwer

Juanjo Rué (Freie Universität Berlin)

Arithmetic removal lemmas and independent sets in hypergraphs

Friday 12:20 – 12:50, Sala Nicolau d'Olwer

Colin McDiarmid (University of Oxford)

Counting and typical parameters for phylogenetic networks

Saturday 16:30 – 17:00, Sala Nicolau d'Olwer

Dieter Mitsche (Université Nice Sophia-Antipolis)

On rigidity with sliders, orientability and cores of random graphs

Saturday 17:10 – 17:40, Sala Nicolau d'Olwer

Guillem Perarnau (McGill University, Montreal)

Acyclic edge colourings of graphs with large girth

Saturday 17:50 – 18:20, Sala Nicolau d'Olwer

Ignasi Sau (CNRS, LIRMM, Montpellier)

On the Erdős–Pósa property for minors of graphs

Saturday 18:30 – 19:00, Sala Nicolau d'Olwer

Lefteris Kirousis (National and Kapodistrian University of Athens)

On the algorithmic Lovász Local Lemma and acyclic edge coloring

ON THE ALGORITHMIC LOVÁSZ LOCAL LEMMA AND ACYCLIC EDGE COLORING

LEFTERIS KIROUSIS

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The algorithm by Moser and Tardos for the Lovász Local Lemma gives a constructive way to prove the existence of combinatorial objects that satisfy a system of constraints. In this talk, I will first present an alternative probabilistic analysis of the algorithm that does not involve counting witness-trees, neither reconstructing the history of the algorithm from the witness tree. I will then use this approach to show, in a fairly simple way, that a graph with maximum degree Δ has an acyclic proper edge coloring with at most $3.732(\Delta - 1) + 1$ colors, improving the previous known bound of $4(\Delta - 1)$. Time permitting, I will discuss about applications to other problems as well.

COUNTING AND TYPICAL PARAMETERS FOR PHYLOGENETIC NETWORKS

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It is well known how to count phylogenetic trees (rooted binary trees, either fully labelled or with just the leaves labelled). But what about phylogenetic networks, where we allow reticulation nodes (with indegree 2 and outdegree 1), corresponding to evolutionary processes such as recombination and hybridisation? *Tree-child* and *normal* networks are subclasses of structured phylogenetic networks of particular interest.

We shall find approximate counting formulae for the numbers of labelled general, tree-child, and normal phylogenetic networks on n nodes; and corresponding results for leaf-labelled tree-child and normal networks with l leaves. Further we find the typical proportions of leaves, tree nodes, and reticulation nodes for each of these classes of networks.

ON RIGIDITY, ORIENTABILITY AND CORES OF RANDOM GRAPHS WITH SLIDERS

DIETER MITSCHE

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Suppose that you add rigid bars between points in the plane, and suppose that a constant fraction q of the points moves freely in the plane; the remaining fraction is constrained to move on fixed lines, called *sliders*. When does a giant rigid cluster emerge? Under a genericity condition, the answer only depends on the graph formed by the points (*vertices*) and the bars (*edges*). We find, for a random graph $G(n, c/n)$, the threshold value of c for the appearance of a linear-sized rigid component as a function of q, generalizing results of Kasiviswanathan, Moore and Theran. We show that this appearance of a giant component undergoes a continuous transition for q smaller than or equal to $1/2$ and a discontinuous transition for q bigger than $1/2$. In doing that, we introduce a generalized notion of orientability interpolating between 1- and 2-orientability, of cores interpolating between 2-core and 3-core, and of extended cores interpolating between $(2+1)$-core and $(3+2)$-core; we find the precise expressions for the respective thresholds and the sizes of the different cores above the threshold. In particular, this proves a conjecture of Kasiviswanathan, Moore and Theran about the size of the $(3+2)$-core.

ACYCLIC EDGE COLOURINGS OF GRAPHS WITH LARGE GIRTH

GUILLEM PERARNAU
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An edge colouring of a graph G is called *acyclic* if it is proper and every cycle contains at least three colours. We show that for every $\varepsilon > 0$ there exists a $g = g(\varepsilon)$ such that if G has maximum degree D and girth at least g then it admits an acyclic edge colouring with at most $(1+\varepsilon)D$ colours.

ARITHMETIC REMOVAL LEMMAS AND INDEPENDENT SETS IN HYPERGRAPHS

JUANJO RUÉ

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In the last years, several authors have studied sparse and random analogues of a wide variety of results in extremal combinatorics. Very recently, due to the work of Balogh, Morris, and Samotij, and the work of Saxton and Thomason on the structure of independent sets on hypergraphs, several of these questions have been addressed in a new framework by using the so-called containers in hypergraphs.

In this talk I will present how to use this technology together with arithmetic removal lemmas due to Serra, Vena and Kral in the context of arithmetic combinatorics. We will show how to get sparse (and random) analogues of well-known additive combinatorial results even in the non-abelian situation.

ON THE ERDŐS–PÓSA PROPERTY FOR MINORS OF GRAPHS

IGNASI SAU

(in collaboration with D. Chatzidimitriou, S. Fiorini, G. Joret, J.-F. Raymond and D. M. Thilikos)

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A class of graphs C satisfies the *Erdős–Pósa property* if there exists a function f_C such that, for every integer k and every graph G, either G contains k vertex-disjoint subgraphs each isomorphic to a graph in C, or there is a subset S of $V(G)$ of at most $f_C(k)$ vertices such that $G \backslash S$ has no subgraph in C. Erdős–Pósa (1965) proved that the set of all cycles satisfies this property with $f(k) = O(k \log(k))$. Given a connected graph H, let $M(H)$ be the class of graphs that contain H as a minor. Robertson and Seymour (1986) proved that $M(H)$ satisfies the Erdős–Pósa property if and only if H is planar. When H is planar, finding the smallest possible function $f_{M(H)}$ has been an active area of research in the last years. In this talk we will survey some recent results in this direction, and we will discuss other variants of the Erdős–Pósa property such as the case where the k subgraphs have to be edge-disjoint or the case where $M(H)$ is the class of graphs that contain a graph H as a topological minor.

CYCLE PACKING

BENJAMIN SUDAKOV

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Over 50 years ago, Erdős and Gallai conjectured that the edges of every graph on n vertices can be decomposed into $O(n)$ cycles and edges. They observed that one can easily get an $O(n \log(n))$ upper bound by repeatedly removing the edges of the longest cycle. We make the first progress on this problem, showing that $O(n \log(\log(n)))$ cycles and edges suffice. We also prove the Erdős–Gallai conjecture for random graphs showing that whp $G(n, p)$ (for most values of p) can be decomposed into a union of $n/4 + np/2 + o(n)$ cycles and edges, which is asymptotically tight.

Index of Speakers