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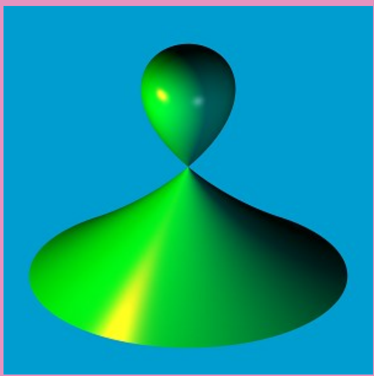

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July 2022

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IMTech Newsletter

Issue 3, July 2022

Virtual ICM 2022

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Editorial

Two **IMTech** members, Maria Alberich Carramiñana and Marta Casanellas Rius, have been recently appointed as Full Professors of the DMAT. The jury assigned to judge the contest celebrated the public session on June 7th, 2022. It was constituted by Professors Eva Miranda (Chair), Amadeu Delshams (Secretary), Antonio Campillo, Carlos D'Andrea, and Víctor Rotger.

C. D'Andrea, E. Miranda, A. Campillo, V. Rotger, A. Delshams.

On the occasion of this happy event, the NL held interviews with the new Professors: see ▷M. Alberich and ▷M. Casanellas. They were formally appointed by the UPC Rector on July 21st, 2022, together with Sonia Fernández-Méndez (we hope to hold an interview with her for next issue!). The other interviews in this issue have been with: ▷Sergi Elizalde, ▷Roger Casals, ▷Maria Bruna, and ▷Pedro Díez.

We also rejoice in congratulating Eva Miranda for several important distinctions: The Bessel Prize 2022 (Awarded annually by the Alexander von Humboldt Foundation, it selects approximately 20 internationally renowned academics from abroad in all areas of Science, Humanities and Engineering in recognition of their outstanding accomplishments in research); she has been appointed as the 2023 Hardy Lecturer for "her high reputation as a research mathematician, who can also speak effectively to a broad mathematical audience" (With this recognition, she joins a list of former Hardy Lecturers awarded biannually by the LMS that includes Dusa McDuff, Terence Tao, and Peter Sarnak); she (and also Ramon Codina) has obtained an ▷ICREA Academia Prize (edition 2021) and one of the four 2022 BBVA Foundation Research Projects in Mathematics with the title *Computational, dynamical and geometrical complexity in fluid dynamics*; in July 2022 she joined the editorial board of JEMS; and she delivered the **IMTech** ▷Spring Colloquium.

In this issue you can find ▷Guillem Blanco's research note about his solution of Yano's conjecture. We take the opportunity to celebrate that his PhD thesis, which was featured in the NL02 (page 9), was awarded the IEC Prize in Mathematics, the UPC Outstanding Doctoral Award and the Vicent Caselles Prize.

Tere Martínez-Seara's Fest (5-9 July, 2022) was announced in the NL02 (page 22). In this issue you can find a ▷Research focus contributed by her and a ▷Chronicle on the Fest.

Pau Mir won the 2022 Évarist Galois Prize of the SCM with the memoir *The geometry of cotangent models and applications to stability theory and quatization*. Our warmest congratulations.

Congratulations also to Jezabel Curbelo for her recent appointment as editor in charge of Research Centers for the EMS Magazzine. This Newsletter held an interview with her in its first issue: NL01, page 3.

We are also glad to congratulate Jordi Tura (see the interview with him in the NL02, page 6) for having been awarded the (triannual) Young Scientist Prize (YSP) of the Atomic, Molecular, and Optical Physics Division (AMOPD) of the European Physical Society (EPS), "for his pioneering work in quantum information theory, in particular in quantum non-locality in many-body systems", and for having been laureated with a 2022 Heineken Young Scientists Award, whose jury praised "his pioneering contributions to the theory of quantum entanglement and nonlocality".

ICM 2022

In principle it should have been held in Saint Petersburg, Russia, but in fact it was held in Helsinki from 6 to 14 July, mostly virtually and with free inscriptions. What triggered this alternative organization is well known: the invasion of Ukraine by Russia on 24 February 2022. It was a wise move of the IMU, as the traumatic war kept raging during the ICM and is still going on six months later, with no end in sight. The details of the IMU decisions can be found in this statement (26 February) and its supplement (27 February).

Now all the lectures and activities of the Congress can be accessed at the vICM. Our deep gratitude to the IMU and all people and institutions that contributed to a successful vICM.

The Fields Medal lectures were delivered on 6 July. It was a memorable day, for the clarity and quality of the lectures. To make them more accessible, particularly to young mathematicians, **IMTech** has organized a set of talks at the FME as follows:

❑ Wednesday 21st September, 12:30–13:30:

- Anna de Mier on June Huh (*algebraic combinatorics and geometry*)
- Guillem Perarnau on Hugo Duminil-Copin (*probability and statistical physics*)

❑ Wednesday 5th October, 12:30–13:30:

- Eva Miranda on Maryna Viazovska (*Fourier analysis and sphere packing*)
- Juanjo Rué on James Maynard (*prime numbers, number theory*)

Sergi Elizalde is full Professor at Dartmouth College. His research focuses on enumerative and algebraic combinatorics, particularly on permutations and lattice paths. He also works on applications of combinatorics to computational biology and dynamical systems, including cancer research. He holds a degree in Mathematics from the FME of the UPC (2000), and a PhD degree in mathematics from MIT (2004) supervised by Richard Stanley. He also holds a professional degree in piano from the Music Conservatory of Terrassa. After graduating in 2004 he was a postdoctoral fellow at MSRI in Berkeley, and joined Dartmouth College in 2005. His extensive service work in Dartmouth includes being House Professor of the East Wheelock House Community and being the Byrne Advisor in charge of guiding undergraduates through enrichment opportunities, both since 2016. He has supervised 7 PhD students and is currently supervising 2 more. Since 2021 he is chair of the Department of Mathematics.

He was awarded a "La Caixa" Foundation fellowship in 2000, the PhD Thesis Extraordinary Award by UPC in 2006 (*Consecutive patterns and statistics on restricted permutations*, advisor Marc Noy), and the Dean of the Faculty Award by Dartmouth College for Outstanding Mentoring and Advising in 2018. He has been awarded numerous grants by NSF, NSA and the Simons Foundation, among others.

NL. ***Which memories do you have as a student at UPC and how did your training at the School of Mathematics influence your academic career?***

My first FME memories are actually from my last year of high school, when I participated in Josep Grané's trainings for the Mathematical Olympiad. That was an invaluable experience, which influenced my choice to attend FME, and ultimately shaped my path into an academic career in mathematics. Of course, I also have very good memories of my time at FME as a student. Being a small program, it created a very tight-knit group of students, as well as many opportunities to interact with the faculty. I still keep in touch with many of my FME classmates despite living in another continent.

At FME I received a very strong education in many areas of pure and applied mathematics, which prepared me to later become a graduate student at MIT and have a relatively smooth transition. I'm indebted to some professors who were very generous with their time, including Profs. Grané, Noy, Pascual, Xambó and many others.

What led you to the field of combinatorics, and what made you decide to go to MIT for a PhD? What reminiscences do you have from your time at MIT?

The first problem that I remember becoming very interested in was the enumeration of polyominos, on which I did a small project in Claudi Alsina's class during my first year at FME. I was mystified by the fact that, despite its apparent simplicity, no formula was known for the number of polyominos with a given area. Later, in my fourth year, I took a class in combinatorics with Marc Noy and Oriol Serra, which became my favorite class. I also worked on a research project with Marc Noy on consecutive patterns (still my most cited paper to date), which motivated me to apply to the PhD program at MIT.

Before that, there was also one particular event that changed the course of my career. The summer before I took that combinatorics class, UPC was hosting FPSAC'99, which is the major annual international conference in algebraic combinatorics. I didn't attend the talks, since I barely knew what combinatorics was at that time, but my classmates and I helped the organizers by baking cakes for a coffee break. At that coffee break, I met a few conference participants, including Mark Skandera, who at that time was a graduate student of Richard Stanley at MIT. Later that same day, I saw a poster advertising the "La Caixa" fellowships for graduate studies in the US, so I decided to apply, and that was one of the best decisions I have made in my life. Richard Stanley would eventually become my PhD advisor.

My four years at MIT were unforgettable. I learned a lot, not only about mathematics but also about life in general. First I was a little intimidated by the fact that many of my peers had been gold medalists at the IMO, and were certainly smarter and more knowledgeable than me. But I loved the culture of helping each other that we had among MIT graduate students, and I was quickly able to fit in. I made friends from every corner of the world, with very different backgrounds, but having in common that we had all moved very far away from our families and were adapting to a new environment.

Which are the main open questions in your area of research? Which problems would you like to see solved in the coming years?

I've always been interested in problems about describing bijections between seemingly unrelated sets of combinatorial objects, that can help us understand their structure. Sometimes, even for objects that are easy to describe, no simple bijection is known, as in the case of the Rogers-Ramanujan identities for integer partitions, or in the case of alternating sign matrices and certain plane partitions. An intriguing problem for which I would love to see a bijective proof one day is the symmetry of the q,t-Catalan numbers, which have a simple interpretation in terms of certain Dyck path statistics.

Other outstanding open questions in my area ask for a combinatorial interpretation of certain non-negative integers that arise in representation theory, such as the Kronecker coefficients or the structure constants of the Schubert polynomials. A little further from my field, I have always been fascinated by the P vs NP problem, although I do not expect to see a solution anytime soon.

You also work on applications of combinatorics to other sciences, in particular to cancer research. Could you tell us more about work on this area?

I enjoy having collaborators in other fields and finding connections in unexpected places. Years ago, I became interested in how pattern-avoiding permutations arise in one-dimensional dynamical systems, a topic that I knew very little about. This enabled tools from one area to be used in the other, and it opened a new avenue for research.

More recently, while having drinks with some old Dartmouth friends who are now biologists at the Sloan Kettering Cancer Center, we realized that my mathematical background could help them with a model that they were developing to study chromosome missagregation, a process by which some mistakes occur when cancer cells replicate, resulting in the genetic make-up of a tumor changing over time. We were able to use probabilistic and combinatorial tools to predict the distribution of chromosome copy numbers after many generations, which was validated by experimental data from cancer patients. From this collaboration I have learned to better communicate across disciplines, and we have been lucky to have a paper published in Nature.

You have done a great deal of service work at Dartmouth, from serving in committees to mentoring students and being a 'House Professor'. Could you tell us more about it and how has this affected your academic life?

In the US, most college students live on campus, and their lives revolve around the university, even after classes. At Dartmouth, all the students are assigned to one of six House Communities. As the House Professor of one of them, my family and I live near the residence halls, in a house provided by the university, with a large space to entertain guests. We often host dinners and conversations where students and faculty have the opportunity to interact with artists, musicians, speakers, and other distinguished visitors. This has been an amazing experience where I have developed close connections with many students, while also being able to enjoy world-class performances in my living room.

Separate from this, on the mathematical side, I have also enjoyed teaching and mentoring students at Dartmouth.

You are department chair at Dartmouth since last year. This must be a great responsibility, how is your experience so far?

Being department chair is a big commitment, since there is a lot of work involved in making a department run smoothly. In my first year in this position, I have learned a lot about the inner workings of the university, specifically about faculty recruiting, tenure cases, curricular updates, mentorship of postdocs and junior faculty, hiring and supervision of staff, budgeting, and managing all the different points of view within a department. It is not always easy, but overall I am enjoying the experience.

As a last question, which actions could IMTech consider to attract and retain young talent?

From my experience, some features that attract talent to a particular institution are the location, the quality of the research group, the motivation of the students, the workplace environment, the amount of independence and recognition (feeling valued), and the salary and access to resources. I think **IMTech** already excels in many of these aspects, while others may be difficult to change if they depend on external factors.

Roger Casals is an Associate Professor at UC Davis. His research focuses on contact and symplectic topology, also on the theory of h-principles, with work in areas such as contact and symplectic structures in higher-dimensions, the theory of Lagrangian fillings of Legendrian knots, the study of Engel structures in 4-dimensions and, more recently, the microlocal theory of sheaves.

He holds a degree in Mathematics from the FME of the UPC, reinforced in the last two terms with his enrollment in the Research Summer program sponsored by CSIC JAE INTRO. Then he earned a Master's Degree in Mathematics from the UCM, supervised by Vicente Muñoz and Francisco Presas, and a PhD in Mathematics from the UAM and ICMAT-CSIC, supervised by Francisco Presas (*Contact fibrations over the 2-disk*). Before his current tenured position (2022), he was a CLE Moore Instructor at MIT, then he spent one year at the University College London, and in 2018 he took an Assistant Professorship position at UC Davis.

He was awarded a fellowship of "La Caixa" Foundation for his Master's Program; the "Extraordinary Thesis Prize" 2014-2015 by the UAM; the "Outstanding Thesis Award" 2014-2016 by Red Española de Topología; the 2015 José Luis Rubio de Francia Prize (which carries a start-up grant) and the 2016 Vicent Caselles Prize, both awarded by the RSME and the FBBVA; a 2019 NSF CAREER Award (*Legendrian and Contact Topology in Higher Dimensions*); and a 2020 Sloan Fellowship.

NL. ***Your journey into research from your undergraduate studies up to your PhD in Mathematics is somewhat unusual, if only by the number of institutions and people involved. Could you reminisce what were the main influences, research experiences, and results of that period?***

I was genuinely fortunate to spend time at all these departments, being exposed to different areas of mathematics and styles of research was beneficial to me. The interaction with many of my peers and professors made the daily experience of delving into research truly pleasant. Marta Farré, Hector Barge and Ángel D. Martínez come to mind as some of the colleagues with whom I shared the start of this journey; I often found that much inspiration and motivation could be drawn by spending time with my peers. I was also lucky with regards to the classes and seminars I had the chance to attend. I think the mental clarity and ideas of Vicente Muñoz, who run a gauge theory seminar, and José María Montesinos, who taught a topology course, left an important mark on me: it certainly made me have much higher standards when it came to understanding mathematics, and they also opened to me a world of geometric and visual ideas that I still use to this day.

How do you value the prizes you were awarded in recognition of the quality of your early work?

I cherish the opportunity to share pieces of mathematics that I find exciting with the broader mathematical community. The different awards and prizes that I have had the honor to receive have presented wonderful chances for outreach and dissemination within and outside the mathematical community. They allow us to share the beauty and excitement of a specific breakthrough with other mathematicians too, and this is an important component for scientific progress and mathematical cross-pollination. There are also many outstanding results that sometimes do not attract recognition in the same manner and we as a community must keep working to maintain healthy levels of mathematical communication and inclusivity, with seminars, conferences and discussions about all sorts of recent results, e.g. à la Séminaire Bourbaki, the Notices and the Bulletin of the AMS or the Newsletter of the EMS. I also think that we should be particularly encouraging and supporting early career researchers, i.e. graduate students, postdoctoral fellows and tenure-track faculty, and awards and grants such as the Vincent Caselles and José Luis Rubio de Francia (by the RSME and FBBVA) are excellent initiatives in that regard.

Afterwards you landed at MIT. How did this come about? What were your main scientific interactions there? Which of your discoveries occurred during this period?

Thanks to the support system that the UAM and ICMAT-CSIC have for the graduate students, I spent time in the US during my graduate years talking to specialists in my field. Two people I got to know were Viktor Ginzburg and Yakov Eliashberg, both of which wonderfully welcomed me to the area of contact and symplectic topology, and I learned a lot from their depth of ideas, insight and generosity. I think this influenced me when deciding to take a postdoc in the US, at MIT as you say. Moving to MIT made me really happy, both Boston-Cambridge as a city and the overall scientific environment in the Math Department resonated well with me and I had very productive years there. In my area, I mostly talked to Paul Seidel and Emmy Murphy and I started many interesting projects during those years, including a collaboration with Eric Zaslow that is still leading to new results many years after. In 2015-17 I was mostly focused on higher-dimensional contact and symplectic topology (both from the h-principle and the Weinstein handlebody perspectives) and Engel structures, and at the end I had already a fair amount of work on Lagrangian fillings, weaves and spectral networks.

How about the year you spent at UCL?

I wish I had enjoyed the Math Department at UCL more, but I had the entire year scheduled already and had to spend many months in conferences and workshops all around, including China and the US. I was glad to meet Angela Wu there, a master student at UCL, and I ended up directing her master thesis. She moved forward to a PhD thesis in 3-dimensional contact topology with Steven Sivek at Imperial, and is now an active researcher in the field. The UK has a strong group in symplectic topology, including Jonny Evans, Ailsa Keating, Nick Sheridan, Ivan Smith and others, and they have been producing beautiful mathematics and quite capable PhD students for many years now, which is to be praised.

In the last four years, your academic home has been UC Davis/Mathematics and recently you have been appointed to a tenured position. Could you sketch how is this rich milieu organized, and how your teaching and research fits into it?

The Math Department at UC Davis has been a fantastic place to be, I have a lot of freedom in choosing (and deciding how to proceed in) the three main aspects of my current position: research, service and teaching. With regards to research, there is a lot of activity in the department, as we have a large Geometry & Topology group and my faculty colleagues are overall outstandingly productive. This sets a high standard and good tone throughout the department. I have been collaborating with some of them, Eugene Gorsky and independently Andrew Waldron, trying to connect my research to other areas and, at the end, just enjoying learning and thinking about new mathematics. I currently have two post-doctoral researchers under my supervision and also graduate students, and sharing with them parts of my research program as well as encouraging them to develop their own has been an enjoyable experience. I have been teaching several graduate classes, including a topics class on contact topology, which is great, and I also particularly enjoy teaching the freshman undergraduate classes.

What are the main outcomes of your research endeavors during the UC Davis period?

I have been working on many different projects since 2018, including work on contact and symplectic topology, but also mathematical physics, singularity theory and more recently in the study of cluster algebras, which is more closely related to commutative algebra and Lie groups. In the first year I focused on codimension-2 contact submanifolds, including the proof of an h-principle, with Francisco Presas and Dishant Pancholi, and then a new construction of rigid examples, with John Etnyre. Then I started shifting towards studying Lagrangian fillings and learning about the microlocal theory of sheaves. That lead to the result that most max-tb Legendrian torus links have infinitely many fillings: this is an article (arXiv pdf) that I wrote with Honghao Gao, with whom I had been fruitfully talking with for many years and I was really happy to collaborate with him. Of course, in between all these I have been enjoying many other mathematics, including a project relating toric mutations and ellipsoid embeddings, which developed from hanging out with Renato Vianna in Brasil. (Incidentally, IMPA in Rio de Janeiro became one of my favorite places to visit.)

What problems in areas of your interest would you like to see solved in the coming years?

For one, I would love to understand the connected components of the compactly supported symplectomorphism group of the $(2n)$-dimensional symplectic Darboux ball, for higher n. Many interesting problems relate to that. In general, I would like to see a theory developed to tackle problems in higher-dimensional contact and symplectic topology, e.g. how many Lagrangian fillings does the standard n-dimensional Legendrian unknot have, how many symplectic lines are there through two points in complex projective spaces, whether either of two components needs to be Weinstein fillable so that Weinstein connected sum is Weinstein fillable, and so on. The theory of pseudo-holomorphic curves addresses these in 3- and 4-dimensions, but the methods do not seem to work in higher dimensions for a variety of reasons: maybe we need to improve them, or just have a genuinely new idea with a different set of techniques. Finally, and I am biased for this one, I would like to see the ADE Conjecture on Lagrangian fillings of Legendrian knots resolved.

What message are the geometric objects in your picture supposed to convey?

The most important lesson I learned during my early formative years was that geometric thinking goes a long way and it is worth spending time developing it. Whether it is actual drawing, or visualizing, or developing any kind of geometric intuition, spending time understanding the actual geometric reasons that explain a given mathematical result has always been productive for me. Even if a statement is presented as an algebraic or analytic result, completely withdrawn from any apparent geometric meaning, I always like to embark in the quest to understand whether there is a geometric theory behind it that would explain, and sometimes (re)prove, that result. This is a personal taste of mine; although it is often serious struggle to develop such geometric proofs and intuitions, I find that, for me, algebraic equations and analytic inequalities come to brighter life when there are pictures behind them. Probably the first person I learned this from was Xavier Cabré (ICREA-UPC) in his advanced PDE class at FME: discussing functional inequalities as geometric problems (e.g. isoperimetric ones), and also deducing PDEs from probabilistic questions, was inspiring. The second person that I saw do this successfully was Ignacio Sols (UCM), with whom we learned some aspects of number theory from the (algebraic) geometric viewpoint. In short, all I like to convey is that drawing and visualizing can be a welcoming and refreshing way to understand and do mathematics.

Dennis Sullivan has been awarded the 2022 Abel Prize. Could you comment on aspects of your research inspired by his works?

The work of Dennis Sullivan has had an important influence in the development of string topology, which is closely related to aspects of symplectic topology. I have myself been developing results in a different area of contact and symplectic topology, influenced more by Mikhail Gromov, who was awarded the 2009 Abel Prize, and especially Vladimir I. Arnol'd, who also was awarded several prizes, including the 2008 Shaw Prize and the 2001 Wolf Prize. I started reading the works of Arnol'd in graduate school, focusing on singularity theory and then the study of wavefronts and caustics. I enjoyed the wealth of ideas and connections that he draws in his books and articles. His writing style leaves a fair amount for the reader to do and think about, but I found that exciting and it motivates me to fill in the gaps. To this day I still use his texts in ODEs, PDEs and singularities with my undergraduate students, so they learn to think for themselves and develop the healthy habit of proving things by yourself.

Maria Bruna is an Assistant Professor at the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge. Since 2019 she has held a Royal Society University Research Fellowship on *Continuum models and gradient flows of interacting particle systems*.

Her research field is in stochastic modelling and homogenisation techniques in mathematical biology and industrial mathematics. In particular, she is interested in multiscale methods that can capture phenomena of many-particle systems at multiple scales and explain how individual-level mechanisms (such as the interactions between particles) affect the population-level behaviour. Her work on homogenisation has led to partnerships with Pall Corporation and Dyson Ltd to improve the efficiency of filters in air purification.

She has degrees in *Industrial Engineering* and *Mathematics* from UPC/CFIS, an MSc in *Mathematical Modelling and Scientific Computing*, and a PhD (2012) from the Mathematical Institute at the University of Oxford. She has worked as a postdoctoral researcher at the Department of Computer Science in Oxford and Microsoft Research (Cambridge) within the *Computational Ecology & Environmental Science* group.

In 2013, she received a Junior Research Fellow in Mathematics at St John's College, Oxford, and became a member of the Wolfson Centre for Mathematical Biology at the University of Oxford. In 2015 she was awarded an Olga Taussky Pauli Fellowship at the Wolfgang Pauli Institute in Vienna. In 2016 she received a L'Oréal-UNESCO Women in Science Fellowship (see An Interview with Maria Bruna) and the Women of the Future in Science prize. In 2017 she was awarded a Humboldt Research Fellowship by the Alexander von Humboldt Foundation. In 2020 she was awarded the Whitehead Prize by the London Mathematical Society (see the Citation and the interview Taming complexity).

NL. ***What were the main decisions you made to become a CFIS student? How do you value that education with respect to your development until today?***

Becoming a student of CFIS didn't quite feel like a decision; in fact, I can't remember taking it! I wasn't sure what to study at university, so I decided to go for Industrial Engineering at the UPC as it seemed pretty broad. But once I started, I realised I was enjoying more the mathematics and physics courses and less the non-technical ones. At the time, I think CFIS had just formally launched, offering a range of double degrees, including mathematics and industrial engineering. I imagine I must have thought I could continue taking maths courses for longer (which no longer featured in engineering from the third year). I never thought I would end up working as a mathematician, though. My CFIS education has been fundamental in my career because it made me feel at ease with interdisciplinarity and approaching problems in nonstandard ways.

Your graduate work (MSc and PhD), was carried on at the Mathematical Institute of the University of Oxford. We would like to know your recollections about that period, including how it shaped your views of mathematics and its relation to science and technology.

While the double degree gave me the foundations in mathematics and engineering, the MSc at Oxford opened my eyes to how to use them together. I became part of the Oxford Centre for Industrial and Applied Mathematics (OCIAM), an environment that seemed designed for me (in fact, since then, a few CFIS students have also gone through it). In Oxford, I saw a different philosophy of how to teach and understand mathematics and experienced first-hand forefront research in applied mathematics. I enjoyed it so much that it made me reconsider my next year and stay in Oxford for a PhD in Applied Mathematics.

You have been awarded several important prizes and distinctions. What influence have they had in promoting your career? Which of them best matches your achievements?

Often one hears that one prize leads to another, and with this logic, the l'Oréal-Unesco Award For Women in Science has made the most difference in my career.

Your present status suggests that the several years of Brexit may not have entailed a hindrance to your professional life. Is that so or otherwise?

Brexit has not directly affected my professional life as I hold dual nationality. Still, it has and will continue to significantly impact education and research and general aspects of life in the UK. So far, we are already seeing a substantial drop in the number of students and researchers from the EU that want to come to Cambridge, and the UK has been left out of Horizon Europe (which will result in less research funding and collaboration opportunities with EU partners). The covid pandemic has somehow helped to hide away the issues due to Brexit, but I believe we will start to see the real impact of it in the coming years.

What personalities, alive or historical, have represented a role-model for your endeavours?

I come from a family of mathematicians, which one may argue influenced my decisions growing up. But I think it was the only non-scientist in the family, my maternal grandmother, who went to university to study history despite many adversities in the post-war years, that was a role model for me. She taught me to follow my instincts and curiosity.

It is fair to say that you yourself have become a role-model, particularly for younger people. What are the main activities you devote to this aspect of your life? What advice would you like to give in that regard?

Being a female mathematician in Cambridge, it is hard to escape the label of role model. The small percentage (<20%) of female undergraduates at Cambridge and even less as you progress to graduate students, postdocs, lecturers, etc. is shocking. Naturally, the university is keen to change that. And one way to do that is through role models, giving disproportionate visibility to the few of us in the faculty, who are drawn into more hiring panels, committees and outreach activities than our male counterparts. So sometimes, it can feel like a balancing act!

How have you managed to reconcile your professional commitments with your family life?

I have been lucky to have research fellowships and grants with no teaching commitments and the flexibility to reconcile both. Still, academia is not a standard job that you can leave when you leave the office, which has negative aspects when you have small children.

Your international experience may allow you to compare the strengths and weaknesses of different science systems. In that regard, what are your views about the Catalan and Spanish systems as compared to others outside that you know best, especially in UK?

The first difference that comes to mind is that of compartmentalisation. The UK is a very fluid system, which not only does not mind but encourages the transfer of knowledge and people between disciplines. To give you an example, in the UK, you can study German as an undergraduate and then go to graduate law school or become a medical doctor with an undergraduate and PhD in mathematics. Even within one discipline, it is not uncommon to go back and forth between academia and industry (for example, hire as a postdoc someone with several years working in a company). This fluidity makes the universities and workplaces more diverse and facilitates funding opportunities (not only that companies want to fund fundamental research, but also, the government can justify to the taxpayer that funding universities is an integral part of the economy).

As a last question, which actions could IMTech devise to attract and retain young talent?

IMTech has enjoyed an advantage over other mathematics departments in Spain thanks to CFIS, which has attracted excellent students over the years. However, in recent years double-degrees have popped up like mushrooms everywhere. In my view, **IMTech** should exploit its defining links with the top engineering schools to remain at the forefront and adapt its offer to meet the current and future needs of applied mathematicians (which involve a lot more of data and computing than 20 years ago). Regarding retaining young talent, this is a difficult one, given the limitations of the Spanish research funding system. Given the extent of the **IMTech** alumni network abroad, I think a good strategy might be to use it so that PhD and postdoctoral researchers at **IMTech** have opportunities to do internships or short postdoctoral stays abroad. At Cambridge, we often have funding for such things, so I welcome any interested people to contact me!

Maria Alberich Carramiñana has recently won a position of Full Professor in Geometry and Topology at Universitat Politècnica de Catalunya (UPC). She is member of the **IMTech** and of the Department of Mathematics (DMAT). She also belongs to the Institut de Robòtica i Informàtica Industrial (IRI, CSIC_UPC) since 2005.

She received her degree in Mathematical Sciences and her PhD in Mathematics from Universitat de Barcelona (UB). Her PhD thesis (1999) established the foundations of the modern theory of the plane Cremona maps and it won the Outstanding Doctoral Thesis Award. She joined UPC in 2001 with a Ramón y Cajal (RyC) postdoctoral position from the first call of this programme. From 2009 to 2017 she was coordinator of the Research group GEOMVAP. Within this group, her research focuses on *Singularity Theory* from the Algebraic Geometry point of view. She also has been working on mathematical modeling in robotics, and at present she is within the European project Clothilde, which is devoted to the robotic manipulation of garments.

NL. ***When did your interest in mathematics arise? How did this interest evolve during your undergraduate studies?***

When I was a child I was very curious about how things worked. My parents thought that I was gifted to be an engineer. As a teenager I was equally interested in humanistic subjects as well as in scientific ones. My father persuaded me to take the scientific path in secondary school, as it included both scientific and humanistic subjects, such as history, philosophy, literature, and languages. In contrast, the humanistic path avoided scientific disciplines. Being Hellenists, both father and mother, they always could teach me an intensive course in ancient Greek and Latin, in case I needed to. At the time of choosing university studies, I opted for mathematics, because I found that math was the basis of all sciences and engineering. During my undergraduate studies I became more and more engaged with mathematics, and in the end I chose to pursue the PhD studies, instead of preparing for the competitive examinations for high school teachers, as I had initially planned.

From your doctoral work until today, you have kept a research agenda in the study of singularities with algebraic geometry techniques. Could you reminisce, to begin with, your experience in the doctoral years?

My PhD advisor was Eduard Casas Alvero and he proposed me to study the plane Cremona maps as thesis topic. Then I found the treatise *Cremona transformations in plane and space* which was published in 1927 by Hilda P. Hudson, who was the first woman to deliver a communication at the International Congress of Mathematicians (ICM), at the ICM 1912 in Cambridge (UK). Her book covered all the classical works on the subject and it was an inspiration for what my PhD thesis would be: making use of techniques from the theory of singularities, I established the foundations of a new theory on plane Cremona maps, generalizing and correcting the classical theory, and providing completely new results. I published my entire doctoral dissertation as the monograph *Geometry of the Plane Cremona Maps* (Springer LNiM 1769), which currently is a reference work in different fields of mathematics.

Since then, and still within pure mathematics, what are your most outstanding experiences and contributions?

Within pure mathematics my contributions may be grouped into three research lines: global geometry of linear systems with applications to dynamical systems, local geometry of plane singularities and valuation theory, and local geometry of surfaces and complete ideals theory. Some of my works are foundational, they develop a new theory or new techniques, which are of current interest to the scientific community, such as the theory of plane Cremona maps, or my works on adjacency of singularities, or on jumping numbers and multiplier ideals. On the other hand, other works provide conclusive results that resolve difficult problems that remained open for decades: this is the case of my works on the Coolidge-Nagata problem of determining which rational curves can be rectified, on the Spivakosvky problem of classifying germs of sandwiched surface singularities, on the Zariski problem of determining plane curve singularities from its polars and on the determination of a closed formula for the minimal Tjurina number of an plane branch. My outstanding experiences are the eureka moments shared with the people I have collaborated with. Among the research duties I really enjoy guiding young people into research and I have dedicated a lot of my time to it: I have advised or co-advised 4 PhD thesis, 16 Master thesis, and 15 undergraduate projects.

After joining the UPC as a RyC postdoc, how did your interest in robotics came into being? What relation does it have with your expertise in singularities?

In the first call of the RyC program I made contact with Professor Carme Torras, because she was interested in recruiting a mathematical profile expert in geometry for her research group. As a consequence of this connection I included in my RyC research statement some applications of geometry to robotics. After winning one of the RyC contracts, I joined UPC and began a fruitful collaboration with her and other members of her research group, working on artificial perception, configuration spaces to avoid robot singularities and robotic manipulation of cloth. The fascination of singularities is that very different areas of mathematics converge in their study: geometry, algebra, topology, combinatorics, analysis, arithmetics or calculus. Although my approach to singularities is from the tools of algebraic geometry, my training in singularities is broad. When I work on robotics problems, I feel like all my experience and training in these different areas is activated to find a solution.

You have also successfully pursued several outreach activities. Can you outline those that have been more relevant? In any case, what is your motivation for such undertakings?

My main outreach activities have been linked to the RSME-IMAGINARY exhibition, which was adapted from the IMAGINARY collection of the Mathematisches Forschungsinstitut Oberwolfach in order to celebrate the first centennial of the Spanish Royal Mathematical Society (RSME). When I was proposed to join the project by Antonio Campillo, the then President of the RSME, I took the undertaking as an opportunity to collaborate in the dissemination of knowledge to society with a great team led by Sebastià Xambó, the general commissioner of the exhibit. Personally I took it as a chance to be able to explain to the general public what the research in singularities really is. In order to delve into this I got funding to develop teaching innovation and outreach projects. And I found that the best way to talk about math was to highlight the value of the interrelationship of Mathematics with the rest of human activity: arts, science and technology.

Since 2019, you are deputy director of the CFIS. What are your roles in that responsibility?

I am responsible for external relations of CFIS with companies and alumni (former students of CFIS), and I take care of the extracurricular offering of complementary training for our students. For instance, I am in charge of the mentoring programme of first year students, the CFIS Research and Business Fair, and the Summer Internship Programme. I am also responsible for inclusion and for promotion of CFIS to secondary school, and I represent the CFIS at the UPCArts and at the UPC's Centre for Development Cooperation.

At the beginning of your new academic position, what are your dreams for the next years?

I have different research challenges that I would like to address. Among them, I would like to work on possible extensions for non irreducible plane curves of Yano's conjecture about the generic roots of the Bernstein-Sato polynomial in topologically trivial deformations. I also find it really interesting to study how these roots change in the family of topologically equivalent singularities. This belongs to what, in my opinion, are the most subtle and difficult problems in singularities: to unravel the topological mysteries of analytic invariants, that is, to reveal to what extent the topology determines an analytic invariant.

What pursuits, other than mathematics, do you enjoy?

I have always had an artistic bent. I enjoy drawing and painting. I love practicing with the sumi-e technique. Sumi-e means ink painting and it is an ancient East Asian technique of monochromatic brush painting in which the artist uses different concentrations of black ink over rice paper. Since this paper does not allow you to paint on nuances or corrections, any brushstroke must necessarily be very expressive. This is a fascinating challenge.

In the mood of Snow's two cultures, what remedy could you propose to close that split in the mathematical studies?

I think that the split in the case of mathematical studies is more fictitious than real, maybe based on old fashioned stereotypes. By looking at FME student activities you will be able to realize that they have a philosophy club, theater groups, musical ensembles,... Besides, Mathematics is a highly creative discipline. I think one of our missions as teachers should be to foster this creativity in our students. I think that creativity can be enhanced by implementing educational environments that promote it by amplifying the outflow of ideas.

Marta Casanellas Rius is Full Professor at the UPC/DMAT (since June 2022) and a researcher at **IMTech** and CRM. She is also affiliated to the BGSMath (since 2015). Her PhD Thesis (2001), *Liason Theory in Arbitrary Codimension*, falls within the field of algebraic geometry and was advised by R. M. Miró-Roig. Her postdoc research (2002-2003), funded with a Fulbright Scholarship, was carried on at the UC Berkeley under the advice of R. Hartshorne and it focused on arithmetically Cohen-Macaulay sheaves.

A major shift from algebraic geometry into applications of algebraic geometry to computational biology, an in particular to phylogenetics, occurred in 2003, the year she obtained a Ramón y Cajal contract at the UPC. The refocusing involved research stays at the Center for Genomic Regulation (2004) and again at UC Berkeley, this time to work with Bernd Sturmfels and Lior Pachter. Her academic involvement in the years since then, as Associate Professor of the UPC/DMAT (since 2007) have been very productive in research, teaching and social leadership.

NL. ***Your early research was in pure algebraic geometry. How did that come about? In your view, what were the main highlights of that period?***

During my undergrad studies I loved pure maths, specially algebra, geometry and topology, so I chose algebraic geometry as the area of my PhD thesis. I did my PhD under the supervision of Rosa M. Miró-Roig and then I went to UC Berkeley for a postdoc. There I started a collaboration with Robin Hartshorne which lead to what I feel are my main contributions from that period: the classification of vector bundles on algebraic varieties using tools from liaison theory.

About the year 2003, your research plans underwent a pioneer move toward applications, particularly to phylogenetics. How did you find out the promising new areas and how did your previous experience relate to them?

When I started with the Ramón y Cajal position, I felt I wanted to contribute with research that had an impact to society. I realized that computational biology would be an excellent area to work on, and at the same time I was starting looking for such a shift, L. Pachter and B. Sturmfels from UC Berkeley published two seminal papers at Proceedings of the National Academy of Science relating computational biology and algebraic geometry. I saw that as my great opportunity for changing research fields. I came back to Berkeley to get in contact with them and their research group and I also visited for half a year Roderic Guigó at the Centre for Genomic Regulation in Barcelona (CRG). They all welcomed me and integrated me in their research groups, which enabled me to change area very fast.

How do you approach the computational aspects of your work?

In our area we need to pass from theoretical results to practical implementations to make our research useful to biologists. We use tools form computational algebra, numerical algebraic geometry and numerical linear algebra to address different aspects of our research: our software for phylogenetic reconstruction relies on numerical linear algebra while we use computational algebra to obtain some of the theoretical results; numerical algebraic geometry is nowadays used to compute solutions of zero dimensional systems of equations, which arise in some problems in phylogenetics.

Do you know of other significant moves from pure algebraic geometry research to other applied fields?

There are many researchers who have moved from pure algebraic geometry to other areas such as chemical reaction networks, error-correcting codes, or robotics for example. A very active area of research nowadays is algebraic statistics, which uses tools from algebraic geometry and commutative algebra to solve problems in statistics. This area has applications in many different fields, ranging from genomics to economics passing through social sciences and medicine.

In the context of your new position as Full Professor, what is your research vision for the coming years?

I envision interdisciplinary teams as the driving force of research. I believe that science advances with the help of each researcher, but it is necessary to make the effort of understanding the problems in other disciplines to provide our tools to areas that may need them. However, in this country it is not easy to do interdisciplinary research because of the separated areas that govern our research calls and evaluations.

Do you have plans to systematize your research findings and expertise so far in a book?

Not for the moment. But one never knows...

Other than research, you have been engaged in many institutional responsibilities and structural innovations in several fronts. To start with, what has been your involvement in promoting research and research facilities?

I was the deputy director of research when the new Mathematics Department was created in 2015. With the governing team, we created the research committee of the Department, designed the calls for financial support for research, we promoted the first Research Days of the Math Department (Jornades de Recerca) and we established the math colloquim in collaboration with FME and other departments related to mathematics. Among other initiatives, we convinced the rectorate to weight students scores in PhD studentship calls by the average grades of each degree, to make these calls less unfavorable for math students. Finally, we put the first stone for the creation of **IMTech** by elaborating the first proposal that was presented to the rectorate.

On the side of teaching and teaching organization, how would you describe your main contributions and achievements?

I feel that my main contribution has been as head of studies of the degree in *Data Science and Engineering* at UPC. This has been a tedious task because it was not exactly being only the head of studies, but also contributing to the creation of the degree. The degree was implemented for the first time on the 2017-18 term and I was named head of studies the next term. We had to establish the regulations for the final degree project, for company internships, for curricular evaluations, for exchange of studies... We have created an excellent offer for elective subjects from scratch. This degree is shared by three centers (FME, FIB and ETSETB), so its management at all levels has been a hard challenge. But I am very happy to have taken this responsibility as this has allowed me to work close with professors from other schools, to work with excellent administration staff and to have a very close connection with students.

How about social leadership? What have been your major concerns and realizations?

Since I become mother (of three) I have been concerned about women underrepresentation in science. I have been involved in Women in Mathematics committes (of the European Mathematical Society and of Real Sociedad Matemática Española) from which I have worked for empowering women mathematicians. At the UPC I've been responsible for the working group on Glass Ceiling, and we have created the so called "Programa d'exempcions docents per a la intensificació de la recerca per permís maternal" in order to compensate the time lost in research during a maternity leave. On the other hand, I have always been involved in dissemination activities and I love to give talks to general audiences or to school kids.

One last question: How do you envision the future of IMTech?

I hope that **IMTech** will play the role of gathering together mathematicians at UPC and promoting their visibility (for example, I hope that at some point it will have funding to help with the organization of conferences). The mathematics developed at UPC have several particularities and **IMTech** could take great advantage from them.

Credit: NASA, ESA, CSA, and STScl. Webb Space Telescope reveals emerging stellar nurseries and individual stars in the Carina Nebula.

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He was visiting professor at École Normale Supérieure de Cachan, École Centrale de Paris and Politecnico di Milano and visiting researcher at Macquarie University (Sydney, Australia) and the Joint Research Center of the European Commission (Ispra, Italy). He has co-chaired the ten editions of International Conference on Adaptive Modeling and Simulation ADMOS, served as Dean of the Civil Engineering School and UPC Vice-Rector for International Policy, coordinating also the participation of UPC in the KIC Innoenergy (2010-2013). He was distinguished with the 2010 IACM Fellow Award.

NL. ***What prompted you to do research in numerical modelling and computational mechanics?***

I would love saying that my vocation started when I was a child and that I devoted all my effort and dedication to the noble art of computational engineering... but this would be an overstatement. However, I always had a genuine interest for mathematics and their application to solve relevant problems. Note that I preferred describing the discipline as "Computational Engineering". If you look at its definition, it matches properly the type of research I do, complementing my engineering background with an academic career in Applied Mathematics. Actually, I also feel comfortable with the descriptor "Mathematical and Computational Modeling". The main point is using numerical models and simulations to have a deeper insight in engineering systems, to predict their behavior and to support decision making. Overall, I find it extremely appealing.

What needs to be changed in academia for improving the transfer of knowledge to industry?

Transfer of knowledge is a matter of communication between two parts. It is not a good starting point considering that knowledge pertains only to the academic side, and that industry is just aspiring to assimilate academic wisdom. In my opinion, applied research is captivating because it offers the possibility of learning from industry. Only after knowing very well the problems they have, and their state-of-the-art knowledge and technology, we are able to offer solutions based on our scientific findings. In short, we need academical curiosity towards industry.

In other words, transfer of knowledge is a synergistic activity, where putting together knowledge and skills from both parts, the resulting outcome largely exceeds the simple sum. In order to achieve this cross-fertilization, we need from both parts stability and flexibility. It is of great importance keeping longstanding steady relations, and assume that this is to be sustained with funds coming both from industry itself and from public bodies.

How has evolved the interest of industry on recruiting PhDs in mathematics and applied sciences?

Part of industrial research and innovation landscape has evolved lately into a system in which doctoral degree holders are highly appreciated. With respect to other European countries, this happened in Spain much later. Some industries do prefer doctors with training in specific disciplines. More dynamical sectors hire researchers valuing their analysis and communication skills, a sound scientific background, and the capacity of concentrating attention in a specific problem. For the latter, PhDs in applied mathematics and other engineering sciences are certainly an excellent asset.

In your view, which are going to be the main contributions of mathematical modelling in science and technology?

The standard role of mathematical models was just to predict the behavior of physical systems, to validate designs, and to make decisions on their optimal control and management. Parametric analysis, optimization, inverse problems or uncertainty quantification were often limited to simple cases due to the unaffordable cost of performing a large number of simulations. We are witnessing an important progress in the field associated with the emergence or reduced-order models, and surrogates generated using different techniques (most, classified under the Machine Learning buzzword). In my opinion, addressing the problem of data assimilation and uncertainty quantification is essential to qualify the credibility of the models; credibility is a concept involving verification (accuracy of the numerical schemes), validation (fitting experimental observations), and assessing the intrinsic aleatory dispersion of the phenomena to be modelled.

In other words, it is undeniable that, describing the behaviour of many engineering systems, mathematical modelling has reached an amazing level of maturity. The models are now accounting for all the phenomena that are relevant. These models depend, however, on many input parameters: geometric characteristics (including dimensions), material parameters (elastic moduli, thermal conductivities, permeabilities, dielectric coefficients, wave numbers...) which have to be provided by the modeller and are often estimated with low accuracy. In this context, two classical problems are gaining importance and become ever more pertinent. First, inverse problems (or data assimilation), that is finding the values of the input parameters that better explain some observed data. Second, uncertainty quantification, that is propagating along the model the uncertainty contained in the data. Note that often uncertainty is described with an epistemic stochasticity, that is associated with the lack of knowledge. Both the inverse problem and the uncertainty quantification require running a large number of forward problems. In that framework, where we face the necessity of finding many solutions of the problem, but all lying in a specific manifold, reduced-order models and surrogates are extremely important. I therefore expect many contributions in these lines.

How do you think IMTech can foster collaboration with industry?

As I said before, an important driving force is curiosity. I would suggest offering spaces to industrial researchers to communicate their achievements, and also their limitations. It is important listening to them and discovering their problems and necessities. This could trigger collaboration. It is not an easy task. Any collaboration (also between academics) requires generosity from both sides, and a great deal of mutual respect. Transfer of knowledge must be bidirectional.

Yano's conjecture

by Guillem Blanco (FWO-KU Leuven)

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The paper [3] solves a long-standing conjecture about the structure of the roots of the Bernstein-Sato polynomial for plane branches posed by T. Yano in 1982 [18].

Let $f : (\mathbb{C}^{n+1}, \mathbf{0}) \longrightarrow (\mathbb{C}, 0)$ be a germ of a holomorphic function. To each such germ, one can associate a functional equation

$$P(s) \cdot f^{s+1} = b_{f,P}(s) f^s \tag{1}$$

between the symbolic powers f^s of f. Here,

$$P(s) = \sum_{i,\alpha,\beta} s^i x^\alpha \partial^\beta$$

is a polynomial in the variable s and having coefficients in the ring of differential operators $\mathbb{C}\{x_0, \dots, x_n\}\langle \partial_0, \dots, \partial_n \rangle$.

The set of all polynomials $b_{f,P}(s)$ appearing in (1) forms an ideal of $\mathbb{C}[s]$. The monic generator of this ideal is called the *Bernstein-Sato polynomial* $b_f(s)$ of f and it is an invariant of the singularities of the zero set $f^{-1}(0)$.

The roots of $b_f(s)$ are known to be negative rational numbers contained in the interval $(-n-1, 0)$ [9, 15] and are related with many other invariants of the singularities as the monodromy eigenvalues, the jumping numbers or the spectrum of the singularity [5, 14]. In contrast with all these invariants, the Bernstein-Sato polynomial is not a topological invariant, that is, it depends on the equation defining f.

In this context, Yano's conjecture predicts that in the case $n = 1$ and if f is irreducible the roots of $b_f(s)$ are completely determined by the topological type if f is generic enough. For the precise statement see Conjecture 1 below. Moreover, Yano's conjecture predicts the value of all the roots of $b_f(s)$ from topological invariants.

In order to state Yano's conjecture we first need a characterization of the Bernstein-Sato polynomial in terms of the Gauss-Manin connection of f. Assume that $f : (\mathbb{C}^{n+1}, \mathbf{0}) \longrightarrow (\mathbb{C}, 0)$ has an isolated singularity at the origin. Let

$$\mu := \dim_{\mathbb{C}} \frac{\mathbb{C}\{x_0, \dots, x_n\}}{\langle \partial_0 f, \dots, \partial_n f \rangle},$$

the Milnor number of f, which is finite since f has an isolated singularity. Consider the Brieskorn lattice of f

$$''H_f^n := \frac{\Omega^{n+1}_{\mathbb{C}^{n+1},\mathbf{0}}}{\mathrm{d}f \wedge \mathrm{d}\Omega^{n-1}_{\mathbb{C}^{n+1},\mathbf{0}}},$$

which is a free $\mathbb{C}\{t\}$–module of rank μ, where the action of t is given by multiplication by f. In addition, it carries a covariant derivative ∂_t that coincides with the Gauss-Manin connection of the singularity.

Theorem 1 (Malgrange [13])**.** *Let*

$$''\widetilde{H}_f^n := \textstyle\sum_{k \geq 0} (t\partial_t)^k \, ''H_f^n$$

the saturation of the Brieskorn lattice $''H_f^n$*. The reduced Bernstein-Sato polynomial* $\tilde{b}_f(s) := b_f(s)/(s+1)$ *of an isolated singularity* f *coincides with the minimal polynomial of the action*

$$\overline{\partial_t t} : {''\widetilde{H}_f^n}/t\,{''\widetilde{H}_f^n} \longrightarrow {''\widetilde{H}_f^n}/t\,{''\widetilde{H}_f^n}.$$

Notice that the last morphism is an endomorphism of complex vector spaces of dimension μ. Then, one defines the b-exponents of f as the roots of the characteristic polynomial of the action of $-\overline{\partial_t t}$. This way, there are always μ b-exponents counted with possible multiplicities.

Let now $f : (\mathbb{C}^2, \mathbf{0}) \longrightarrow (\mathbb{C}, 0)$ be an irreducible plane curve. For this type of singularities, the topological type of the singularity is completely determined by a tuple of positive integers $(n, \beta_1, \dots, \beta_g), g \geq 1$, called the *characteristic sequence*. From this data, define

$$\begin{aligned}
r_i &:= \frac{\beta_i + n}{e_i}, \\
R_i &:= \frac{\beta_i e_{i-1} + \beta_{i-1}(e_{i-2} - e_{i-1}) + \cdots + \beta_1(e_0 - e_1)}{e_i}, \\
r'_0 &:= 2, \quad r'_i := r_{i-1} + \left\lfloor \frac{\beta_i - \beta_{i-1}}{e_{i-1}} \right\rfloor + 1 = \left\lfloor \frac{r_i e_i}{e_{i-1}} \right\rfloor + 1, \\
R'_0 &:= n, \quad R'_i := R_{i-1} + \beta_i - \beta_{i-1} = \frac{R_i e_i}{e_{i-1}}.
\end{aligned}$$

Conjecture 1 (Yano [18])**.** *For generic fibers of some μ–constant deformation of f, the b-exponents $\{\alpha_1, \dots, \alpha_\mu\}$ are given by the generating sequence*

$$\begin{aligned}
R((n, \beta_1, \dots, \beta_g), t) := t + \sum_{i=1}^{g} t^{r_i/R_i} \frac{1-t}{1-t^{1/R_i}} \\
- \sum_{i=0}^{g} t^{r'_i/R'_i} \frac{1-t}{1-t^{1/R'_i}} = \sum_{i=1}^{\mu} t^{\alpha_i}.
\end{aligned}$$

In this context a μ–constant deformation is the same as topologically trivial deformation.

Yano's conjecture was proven in the case where $g = 1$ by Cassou-Noguès [6]. The case $g = 2$ was proved by Artal-Bartolo, Cassou-Noguès, Luengo and Melle-Hernández [1] under the assumption that the eigenvalues of the monodromy are pair-wise different. Under this same assumption, we gave a proof for any $g \geq 1$ in [2].

We will now give a short overview of the proof for the general case. The main idea is to study the asymptotic expansion of periods in the Milnor fiber.

Let $\bar{f} : X \longrightarrow T$ be a Milnor representative of a germ $f : (\mathbb{C}^{n+1}, \mathbf{0}) \longrightarrow (\mathbb{C}, 0)$. Let $X_t, t \in T \setminus \{0\}$ be the Milnor fiber of f. Let ω a section of Ω_X^{n+1} and $\gamma(t)$ a cycle in X_t that vanishes to zero as $t \to 0$, then one has

$$\int_{\gamma(t)} \frac{\omega}{\mathrm{d}\bar{f}} = \sum_{\lambda \in \Lambda} \sum_{\alpha \in L(\lambda)} \sum_{k=0}^{n} a_{\alpha,k}(\omega) t^{\alpha-1} (\ln t)^k, \quad a_{\alpha,k}(\omega) \in \mathbb{C}. \tag{2}$$

where $\omega/\mathrm{d}\bar{f}$ is the Gel'fand-Leray form, Λ is the set of eigenvalues of the monodromy of f and $L(\lambda) = \{\alpha \in \mathbb{Q}_{>0} \mid e^{2\pi i \alpha} = \lambda\}$. The period integrals have such an expansion because they are solutions to the Gauss-Manin connection which has regular singularities [4, 12].

The b-exponents of f appear as a subset of the exponents of the period integrals from (2), hence the name. A theorem of Varchenko [17] gives the necessary conditions under which $a_{\alpha,k}(\omega) \neq 0$ implies that α is a b-exponent.

The relation between the candidates from Yano's conjecture and the asymptotic expansions comes from resolution of singularities. It turns out that the numerical data considered by Yano's conjecture can be interpreted in terms of the numerical data appearing in a resolution of singularities of f.

The main technical result in [3] is the construction of the asymptotic expansions from (2) in terms of the resolution of singularities of f. This generalizes previous results of Varchenko, Lichtin and Loeser [10,11,17] where only the first terms were considered. Although such construction is possible for any germ f, conditions under which $a_{\alpha,k} \neq 0$ are much harder to obtain. However, such results are known for the case of plane curves after a result of Deligne and Mostow [7]. In general, understanding the non-vanishing of the coefficients $a_{\alpha,k}(\omega)$ is an open problem that is related to the Strong Monodromy Conjecture [8].

The last part of the proof is devoted to constructing the particular μ-constant deformation predicted in Conjecture 1. To achieve that we make use of a classical object in the theory of curve singularities, Teissier's monomial curve and its deformation [16]. This part of the proof only works under the assumption that f is irreducible.

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A General Mechanism of Diffusion in Hamiltonian Systems: Qualitative Results (after [7])

by Tere M. Seara (DMAT, IMTech, CRM)

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The paper [7] (see also [8]) solves a version of the Arnold diffusion problem for Hamiltonian systems that remained open since the 1960s.

Hamiltonian systems appear naturally as models of many systems with negligible friction. We could mention, for instance, the models in Celestial Mechanics or the models for motion of charged particles in magnetic fields. Among Hamiltonian systems, integrable systems (systems with enough constants of motion) are characterized because all their orbits lie in maximal invariant tori. Therefore, the motion is stable.

One of the problems that appears naturally in the applications and which has attracted the attention for a long time is whether the effect of periodic small perturbations on integrable systems accumulate over time and lead to large effect (instability) or whether these effects average out (stability).

It is often the case that Hamiltonian systems exhibit both stable and unstable regimes. In fact, beginning in the 60s, there exist rigorous results proving that for the mentioned systems most of the invariant tori persist and therefore most of the trajectories are stable for all the time: this is the well known KAM Theorem (Kolmogorov-Arnol'd-Moser), or they are stable for very long times (Nekhoroshev).

The orbits that do not lie on KAM invariant tori and evolve over time scales where Nekhoroschev theory breaks up may possibly drift arbitrarily far. Indeed, in [1] Arnold conjectured that this is a phenomenon that happens in rather general systems. In that celebrated paper he constructed an example of a nearly integrable Hamiltonian system for which he proved the existence of trajectories that avoided the KAM tori and that performed long excursions.

The example provided by Arnold has the characteristic that the unperturbed system is integrable but presents hyperbolicity (the system has conserved quantities but the motion is not foliated by maximal invariant tori). In fact, it has a manifold foliated by whiskered tori whose stable and unstable manifolds coincide. When the perturbation is applied, the mechanism of diffusion is based on the existence of chains of whiskered tori such that the unstable manifold of one torus intersects the stable manifold of the next one (*transition chains*).

A characteristic of Arnold's example is that the perturbation has been chosen carefully so that it does not affect the foliation of invariant tori present in the unperturbed system, but it causes the stable and unstable manifolds to intersect transversally. But general perturbations destroy the foliation of persisting whiskered KAM tori creating gaps of size bigger than the splitting of the stable and unstable manifolds. Therefore, the transition chains proposed by Arnold can not exist. This is known in the literature as the *large gap problem*.

Generalizations of Arnold's model are the so-called a priori unstable systems and there has been a very active area of research to prove the existence of Arnold diffusion for such systems.

Overcoming the *large gap problem* and identifying new mechanisms for diffusion has become an important direction of study itself. This problem has attracted the attention of both mathematicians and physicists due to its practical importance and mathematical depth. Some works use variational methods to obtain the diffusing orbits in the case of convex Hamiltonians [9].

Other works use geometric methods and follow a different idea: to look at the Normally Hyperbolic Invariant Manifold (NHIM) formed by these whiskered tori. This object is preserved after the perturbation is applied and gives the opportunity for looking at other invariant objects that can play the role of the disappeared invariant tori in the transition chain: the so-called secondary tori, or tori of lower dimension [3], [5].

An important tool developed in [4] and used in lots of works was the use of the so-called scattering map: a map defined in the NHIM which labels the heteroclinic excusions. Understanding this map and finding perturbative formulas for it has been crucial to prove that objects of different dimension or topology can participate in the chains proposed by Arnold.

Using the scattering map several works obtained results on diffusion in models of Celestial mechanics, see for instance [2], [6].

The disadvantage of previous results is that they needed a deep knowledge of the so-called inner dynamics along the NHIM. The work [7] (and also [8]) follows a different approach. It presents a general mechanism to establish the existence of diffusing orbits in a large class of nearly integrable Hamiltonian systems. The approach relies on successive applications of the scattering map along homoclinic orbits to a normally hyperbolic invariant manifold without any knowledge of the invariant objects in the NHIM. We find pseudo-orbits of the scattering map that keep advancing in some privileged direction. Analogously, we find heteroclinic orbits between points in the NHIM. Then we use the recurrence property of the 'inner dynamics', restricted to the normally hyperbolic invariant manifold, to return to those pseudo-orbits. Finally, we apply topological methods to show the existence of true orbits that follow the successive applications of the two dynamics.

This method differs, in several crucial aspects, from earlier works. Unlike the well known 'two-dynamics' approach, the method we present relies on the outer dynamics by the scattering map alone. There are virtually no assumptions on the inner dynamics, as its invariant objects (e.g., primary and secondary tori, lower dimensional hyperbolic tori and their stable/unstable manifolds, Aubry-Mather sets) are not used at all. The method applies to unperturbed Hamiltonians of arbitrary degrees of freedom that are not necessarily convex (a strong hypothesis needed in the variational approach) avoiding several other technical assumptions needed in all the previous works. In addition, this mechanism is easy to verify (analytically or numerically) in concrete examples, as well as to establish diffusion in generic systems.

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PhD highlights

Caterina Tozzi defended her PhD thesis *A theoretical and computational study of the interaction between biomembranes and curved proteins* (pdf), supervised by Professor Marino Arroyo Balaguer, on April 30, 2021, within the UPC doctoral program in Applied Mathematics. Currently, she is a Postdoctoral Researcher at the Oncology department of the Vall d'Hebron Hospital of Barcelona where she is working on a project that aims to integrate advanced imaging analysis with 3D molecular characterization under the supervision of Raquel Perez-Lopez.

Thesis summary. Organelles are the smallest functional parts of eukaryotic cells. Among them, some are membrane-bound such as the nucleus, the endoplasmic reticulum, or the Golgi apparatus, each of them with essential biological functions. In order to accomplish cell functions, membranes enclosing these organelles continuously adapt their shapes through the out-of-equilibrium interaction with macro-molecules, notably proteins. During the life of cells, proteins are main actors in membrane bending dynamics since they have the ability to impinge their curvature onto the membrane, and generate transiently highly curved structures, such as tubes and spherical buds. How proteins can remodel the different organelles has been broadly studied in equilibrium, but a clear understanding of the complex chemo-mechanical problem that drives membrane reshaping out-of-equilibrium is still lacking.

In the first Part of the thesis we develop a general theoretical and computational framework for the dynamics of curved proteins adhered to lipid membranes. The theory is based on a nonlinear Onsager's principle, a variational method for irreversible thermodynamics. The resulting governing equations and numerical simulations provide a foundation to understand the dynamics of curvature sensing, curvature generation, and more generally membrane curvature mechano-chemistry, as illustrated by a selection of test cases. We show that continuum modeling is a powerful instrument to describe the protein-membrane interaction [1]. However, this model does not account for the orientational order of proteins and its derivation lacks a microscopic basis.

To address these limitations, in the second Part of the thesis we develop a mean-field density functional theory to predict the orientational order and evaluate the free-energy of ensembles of elongated and curved objects, such as BAR proteins, on curved membranes. This kind of protein may adopt different states of orientational order, from isotropic to nematic. The theory is tightly coupled to the microscopic properties of the proteins and explains how a density-dependent isotropic-to-nematic transition is modified by the anisotropic underlying curvature of the membrane [2]. This work lays the ground to understand the interplay between the molecular organization of proteins and the membrane shape dynamics. We explore the coexistence of isotropic and nematic phases on differently curved lipid membranes. We explain, both experimentally and through modelling, how a BAR protein binds on differently curved membrane templates and reshapes them based while modifying their microscopic organization. Our results broaden our understanding of the reshaping dynamics by BAR proteins on mechanically constrained membranes, and provide a framework to understand biological responses involving BAR proteins to membrane-mediated mechanical stimuli [3].

Highlited publication: [3]

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Matthew Coulson defended his PhD thesis *Threshold phenomena involving the connected components of random graphs and digraphs* (pdf), supervised by Guillem Perarnau (**IMTech**& DMAT), on 13 December 2021 within the UPC doctoral program in Applied Mathematics at the FME. Currently he is a postdoctoral researcher at University of Waterloo in Canada working with Luke Postle.

The investigation reported in this thesis is about the behavior of some models of random graphs and directed graphs near thresholds for the appearance of certain types of connected components.

Thesis Summary

In the first chapter, the focus is the study of the critical window for the appearance of a giant strongly connected component in binomial random digraphs. Bounds on the probability that the largest strongly connected component is very large or very small are provided. These bounds improve results of T. Łuczak and T. G. Seierstad [2]. The main result is based on a careful analysis of an exploration process.

In the second chapter, the configuration model in the subcritical and barely subcritical ranges is explored. New upper bounds on the size of the largest connected component are obtained. The proofs rely on a new local limit theorem for the sum of independent random variables, which gives explicit error bounds. There are also examples showing that such bounds are tight for some instances.

The last two chapters are devoted to the study of the directed configuration model, a popular model for random digraphs. First, the investigation of the barely subcritical region yields that this model behaves similarly to the binomial random digraph. The main result is a Poisson approximation for the number of long directed cycles in the graph. Finally, the problem of determining a threshold for the existence of a giant weak component in the model is examined, and the outcome goes beyond non-formal results on the topic previously obtained by I. Kryven [3].

Highlighted publication: [1].

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Maximilian Wötzel defended his PhD thesis *Probabilistic and extremal studies in additive combinatorics*, supervised jointly by Juanjo Rué and Oriol Serra, on 26 January 2022 within the UPC doctoral program in Applied Mathematics. Currently he is in the group of Ross Kang at the Radboud University in Nijmegen, Netherlands.

Thesis summary

The general goal in additive combinatorics —historically also called combinatorial or additive number theory— is to study the additive structure of sets in certain ambient groups. Extremal combinatorics studies how large a collection of finite objects can be before exhibiting certain structural requirements. Probabilistic combinatorics analyzes random combinatorial structures, identifying in particular the structure of typical combinatorial objects. Among the most celebrated outputs is the study of random graphs initiated by Erdős and Rényi. A particularly striking example of how these three areas interweave is the development by Erdős of the probabilistic method in number theory and in combinatorics, which exhibits the existence of many extremal structures in additive settings using probabilistic means. The topics in this thesis all lie in the intersection of these three areas, and concern the following problems.

Integer solutions to systems of linear equations. The study of how large a subset of the integers can be before containing solutions to a given system of linear equations is a classical topic in additive number theory. Recent years have seen a lot of developments regarding *threshold results* for certain integer solutions to an arbitrary given system of linear equations, answering the question when one expects the binomial random subset of an initial segment of integers to contain solutions almost surely. The next logical question is the following. Suppose we are in the range that there will exist integer solutions in the binomial random set, how are these solutions distributed? The first chapter of the thesis takes steps towards answering this question by providing sufficient conditions for when a wide variety of solutions follow a normal distribution. Furthermore, it is discussed how, in certain cases, these sufficient conditions are also necessary.

Independent sets in hypergraphs. The method of hypergraph containers is a very general tool introduced independently by Balogh, Morris and Samotij and Saxton and Thomason that can be used to obtain results on the number and structure of independent sets in hypergraphs. The connection with additive combinatorics appears because many additive problems can be encoded as studying independent sets in hypergraphs. For instance, by defining the vertices of the hypergraphs to be the elements of an initial segment of the positive integers and the hyperedges as those elements that form solutions to a given system of linear equations, we have placed the problem studied in the first chapter into the setting of independent sets in hypergraphs. The second chapter of the thesis establishes an extension of a recent asymmetric version of the container method due to Morris, Samotij and Saxton to multipartite hypergraphs.

Sets with bounded sumset. What can be said about the structure of two finite sets in an abelian group if their Minkowski sum is not much larger than the sets themselves? A classical result by Kneser says that this can happen if and only if the Minkowski sum is periodic with respect to a proper subgroup. The third chapter of the thesis establishes two types of results. The first is so-called *robust* versions of classical theorems of Kneser and Freĭman. Robust here refers to the fact that instead of asking for structural information on the constituent sets with the knowledge that their sumset is small, we only require that this holds for a large subset. The second part of the chapter concerns the typical structure of pairs of sets with small Minkowski sum, that is, what if we only want to give a structural statement for *almost all* pairs of sets with a sumset of a given size? We give an approximate structure theorem that holds for almost the complete range of possible sumset sizes that uses the hypergraph container framework introduced in the preceding chapter.

Sidon set systems. Sidon sets are subsets of abelian groups such that all pairwise sums of their elements are distinct and they are well-studied objects in additive number theory. Classical questions regarding Sidon sets are to determine their maximum size or to know when a random set is a Sidon set. In the final chapter of the thesis we generalize the notion of Sidon sets to set systems and establish the corresponding bounds for these two questions. We also prove a so-called *relative density* result conditional on a conjecture on the specific structure of maximal Sidon systems.

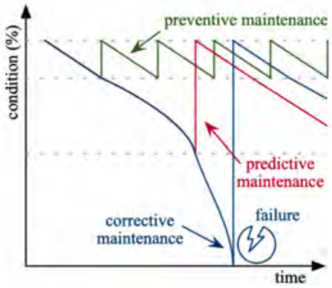
Highlighted publication. J. Rué, M. Wötzel: Normal limiting distributions for systems of linear equations in random sets. *Linear Algebra and its Applications* **649** (2022). Article.

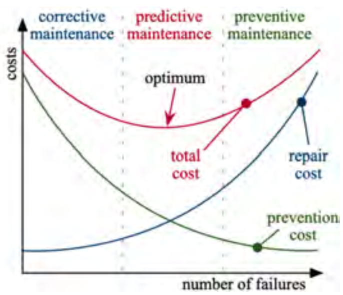
Outreach

Artificial Intelligence for Wind Turbine Predictive Maintenance, by Yolanda Vidal (CoDAlab & **IMTech**).
Received 21 April, 2022.

The world energy system is undoubtedly in transition. The widespread adoption and use of renewable energy are the fastest and cheapest route to greater energy independence after the Ukrainian invasion and are the key to fight climate change. The European Commission's scenarios show renewables-based electrification will be central to delivering climate neutrality in Europe by 2050. To achieve this goal, wind energy is a crucial component, as it is required to be 50% of the European Union's electricity mix with renewables representing 81%. However, the crux of the matter in the advancement of the wind industry is the reduction in its levelized cost of energy (LCOE). The LCOE of a wind farm is determined by combining different factors, being operation and maintenance costs a significant part (20-25% in onshore wind farms and 25-30% in offshore ones). Therefore, a key factor in the achievement of low-cost wind energy is the optimization of maintenance strategies.

Energy production losses due to downtime (caused by unplanned reparation of the assets) together with the costs associated to the replacement of components can scale up to millions of euros per year in any industrial-size wind farm. Thus, it is of paramount importance that the wind industry moves from corrective (repairing components after they break down) and preventive maintenance (scheduled at regular intervals without taking into consideration the actual condition of the asset) to the so-called predictive maintenance (scheduled as needed based on the asset condition). Predictive maintenance is based on actual and timely information collected by monitoring the actual asset through a network of sensors (performed using high-frequency data of physical quantities as vibration, temperature, oil analysis, and acoustic emissions) and provides operators with an advanced warning before the actual fatal fault occurs, thus allowing them to plan ahead and schedule repair to coincide with weather or production windows to reduce costs and turbine downtime. In other words, as shown in the graphics below, predictive maintenance activities are only carried out when they are actually required, that is, the item is not unnecessarily over-maintained, but it will also not fail unexpectedly, thus leading to an optimized cost of maintenance actions. Digitalization and artificial intelligence are key technologies to this strategy, to better exploit the information in the large amount of data (gathered by continuous or periodic, online or offline) from different sensors acquired from the assets. The general framework is to detect changes in the condition that represent deviations from normal operation and indicate a developing fault.





Comparison of corrective, preventive, and predictive maintenance over time with respect to the condition of the asset (left), and comparison of the number of failures and associated costs (right).

Within this framework, the CoDAlab research group has a research line related to the development of advanced predictive maintenance strategies based on artificial intelligence (AI) for the early prediction of failures in wind turbines. The methodologies are validated on real data from 150 wind turbines from different wind farms. This is a crucial resource, and, in this regard, the support and data ceded from the Smartive company is really appreciated, [1].

Predictive maintenance is a wide-ranging area of research and has been successfully deployed to a wide variety of applications. However, its application to complex systems such as wind turbines that are megastructures working under different and varying operating and environmental conditions and in harsh environments (such as offshore) remains an open challenge. Furthermore, the latest developments tend to use expensive specifically tailored sensors, which is not economically viable for turbines already in operation and even less in case they are close to reach the end of their lifespan. This is relevant, as it is expected that 38 GW of wind farms in Europe will reach their life expectancy in the next five years. Based on current trends, it is estimated that about 2.4 GW will be decommissioned for repowering and 7 GW will be fully decommissioned. The remaining 29 GW will continue to operate and will be considered for life-time extension services. In this context, data-driven predictive maintenance methodologies based on existing supervisory control and data acquisition (SCADA) data (available in all industrial-sized wind turbines) are a promising low-cost solution.

As the initial design of SCADA data was for operation and control purposes only, their use for predictive maintenance is a great challenge. SCADA data contain about 200 different variables (that is, it is high dimensional), with a very low sampling rate (it is recorded continuously at 10-minute averaged intervals to reduce transmitted data bandwidth and storage), they depend on the operational region of the WT, as well as on the environmental condition, and they are time series with a strong seasonality. Furthermore, when SCADA systems were built, the value of maintaining standardized maintenance work order logs with detailed fault descriptions was not known (as it was not envisioned that AI could help in this application). On top of this, most of the available data are from normal operation, making them highly unbalanced data sets. Despite these difficulties, lately, the topic of using SCADA data for predictive maintenance purposes has gained increased attention. However, many challenges are still to be addressed in current and future research. The next paragraph highlights the five main challenges in this research area.

First, a significant percentage of publications are based on supervised algorithms (classification methods). Despite their promising performance, in a real application their use is almost precluded as they require historical labeled faulty and healthy data to be constructed. This is an important drawback, as obtaining labeled datasets from wind turbine operational data is typically hard (as maintenance records are not standardized), time-consuming, it is exposed to errors, and leads to a highly unbalanced dataset. Additionally, the methodology cannot be applied straightforward to wind farms where the fault of interest did not occur in the past. Second, a significant number of references use simulated SCADA data or experimental data (from a test bench) to validate the results. Although it is understandable, as real SCADA data sets are often proprietary and are not easily available by the scientific community, it is an important drawback as relying on synthetically generated data may not generalize well to actual real-world conditions. Third, the majority of the literature base their results on a relatively small amount of data, usually only 1 to 4 wind turbines. Thus, it is not clear whether these strategies will generalize well to the whole wind farm. Fourth, some references contribute strategies that lead to a high number of false alarms, thus making the contribution not convenient in the real application as it would end up creating alarm fatigue for operators. Fifth, a non-negligible number of papers detect the fault with less than a week in advance, thus not being helpful in a real application, where the plant operator needs at least months to plan ahead and schedule repair to coincide with availability of replacement parts as well as weather or production windows to reduce turbine downtime.

On this basis, two contributions to highlight from the CoDAlab research group are the following. In [2] a main bearing prognosis strategy is proposed based on a normal behavior model (unsupervised) using an artificial neural network (ANN) with Bayesian regularization. This means that the ANN weights are considered as random variables and their density functions are updated according to Bayes' rule. Furthermore, the Levenberg-Marquardt optimization method is adapted to provide a mathematical reasoning of the hyperparameter setup. Finally, the methodology is validated in a wind farm consisting of 12 wind turbines. In [3] an ensemble learning that combines an ANN (normality model designed at turbine level) and an isolation forest (anomaly detection model designed at wind farm level) algorithms for predictive maintenance of the main bearing is proposed and validated on a wind farm with 18 wind turbines. The normal behavior and anomalous samples of the wind turbines are identified, and several interpretable indicators are proposed based on the predictions of these algorithms. Finally, note that these two references contribute predictive maintenance strategies based solely on wind turbine SCADA data that address the aforementioned five main challenges: i) Entirely unsupervised (not requiring the labeling of data through work order logs) based only on healthy data, thus expanding its range of application to any wind farm (even when no faulty data has been recorded yet). ii) Validated on real (not simulated or experimental) SCADA data. iii) Validated at wind farm level. iv) Reliable predictions with minimum false alarms thanks to specially designed fault prognosis indicators. v) Early warning months in advance.

Finally, near future work is devoted to wind turbine digital twins (DT). A DT is an up-to-date representation, a model, of an actual physical asset in operation. It can be a model of a component (gearbox, generator), and it reflects the current asset condition and includes relevant historical data about the asset. DTs can be physics-based (from first principles involving mechanical, hydraulic, and electrical components), data-driven (for example by artificial intelligence or statistical approaches), or a combination of both. The models reflect the operating asset's current environment, age, and configuration, which typically involves direct streaming of asset data into tuning algorithms that can use artificial intelligence methodologies. Once the digital twin is available and up-to-date, it can be used in different ways to predict future behavior. Notable examples are to include sensors in the DT that are not present on the real asset, simulating future scenarios to inform current and future operations, or using the digital twin to extract current operational state by sending in current real inputs. Therefore, as previously indicated, immediate future work is related to the development of wind turbine DTs for prognostics and health management.

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Chronicles

Abel prize 2022

by Daniel Peralta Salas (CSIC and ICMAT)

Received June 12th, 2022

The **Abel prize** 2022 was announced last March 23th by the president of the Norwegian Academy of Science and Letters. The recipient was Dennis P. Sullivan, distinguished professor of mathematics at the Stony Brook University and the City University of New York.

The citation of the Abel committee read "for his groundbreaking contributions to topology in its broadest sense, and in particular its algebraic, geometric and dynamical aspects", and highlighted his work in algebraic topology (in particular, his proof of the Adams conjecture), and the solution to a 60-year-old conjecture by Fatou on holomorphic dynamics. The striking fact of this brilliant mathematician is that he could have been awarded with the **Abel prize** for other of his contributions as remarkable as those mentioned in the citation. Who is then Dennis Sullivan, a mathematician that was able to change the landscape of different mathematical theories, from topology to dynamical systems and foliations?

Sullivan was born in Port Huron, Michigan, in 1941. He obtained his PhD in Mathematics at Princeton University in 1966, under the supervision of the famous topologist William Browder. His thesis was focused on triangulations of topological spaces. During the late 1960s and 1970s Sullivan worked on several aspects of algebraic topology, developing new and deep ideas to classify manifolds, such as the localization and completion of a space at a prime, rational homotopy theory and Lipschitz structures. All these influential contributions appear in the **Abel prize** citation. Sullivan joined the IHES in Paris in 1974, until he definitely moved to New York in 1997.

In the mid 1970s he became interested in several aspects of dynamical systems and the theory of foliations. In his influential article *Cycles for the dynamical study of foliated manifolds and complex manifolds*, published in Inventiones Mathematicae in 1976, he introduced the theory of foliated cycles. This article is in the top 10 of the most cited works of Sullivan. Although it was not included in the **Abel prize** citation, it is one of his most remarkable contributions, being source of inspiration and method for many mathematicians (among whom I include myself). In this article, Sullivan unified dynamics and geometric structures, and gave a new perspective on apparently very different objects. The key tool he introduced to achieve this was the space of cone structures on a manifold M, i.e., a continuous field $(C_x)_{x\in M}$ of closed convex cones C_x with compact base in the space of k-vectors $\Lambda^k T_x M$. SULLIVAN showed that to any cone structure there is associated a convex cone in the space of k-currents. I recall that the space of k-currents $\mathcal{Z}^k(M)$ is the continuous dual of the space of smooth k-forms on M. With this simple starting point, and using in a very clever way the celebrated Hahn-Banach theorem to construct functionals that separate a cone from a linear space, SULLIVAN was able to prove astonishing results concerning very different topics. For example, he gave a homological characterization of volume-preserving dynamical systems, provided new insights on Novikov's theorem of codimension one foliations and characterized those closed manifolds that are symplectic.

In the particular case of the theory of dynamical systems, SULLIVAN's approach has been particularly influential. Let me introduce it briefly. Given a vector field X on M, the space of foliation currents is the set of 1-currents that can be approximated arbitrarily well (in the weak topology) by a convex linear combination of delta currents in the direction of X. The foliation cycles are then those foliation currents whose kernel contains the space of exact 1-forms. The space of foliation currents is a convex cone with compact base, so it fits within SULLIVAN's framework of cone structures. He observed that the foliation cycles of a vector field are in one to one correspondence with its invariant measures. A beautiful example to show the power of SULLIVAN's theory is his classification of geodesible fields, i.e., vector fields all whose orbits are geodesics for some Riemannian metric. He proved that X is geodesible if and only if no foliation cycle can be arbitrarily approximated by the boundary of a tangent 2-chain. In particular, if X has Reeb cylinders, it cannot be geodesible. Very recently, in a joint work with FRANCISCO TORRES DE LIZAUR and ANA RECHTMAN (A characterization of 3D steady Euler flows using commuting zero-flux homologies, *Ergodic Theory & Dynamical Systems* **41**/7 (2021), 2166-2181), we have generalized Sullivan's characterization of geodesible flows to include all stationary solutions of the Euler equations of hydrodynamics, one of SULLIVAN's passions during the last 20 years. Sullivan's theory of foliated cycles is more alive than ever.

In the 1980's SULLIVAN turned his attention to holomorphic dynamics, an area where he also made fundamental contributions. He proved what is known as Sullivan's no-wandering domain theorem, stating that under some conditions every Fatou component of a rational map of degree $d \geq 2$ on the Riemann sphere is eventually periodic. This spectacular result, which solved a conjecture stated by FATOU in the 1920s, also appears in the citation of the **ABEL prize**.

When I met DENNIS SULLIVAN in 2014 at Stony Brook he already was a living legend in mathematics. We participated in a programme organized by the Simons Center for Geometry and Physics on geometrical aspects of hydrodynamics, the topic that has attracted most of his attention during these years. I immediately realized that he likes to discuss about any problem of mathematics. Discussions with him always lead you to new scenarios, to ideas that you had not considered before. His global view allows him to connect different areas in unexpected ways and to point toward the key points of an argument. Understanding for him is more important than statements or formal proofs. During the award ceremony, SULLIVAN's Abel lecture concerned fluid motions, where he presented his ideas based on discrete models and algebraic topology to try to unravel the mystery of the Euler and Navier-Stokes equations. The existence, or not, of singularities during the evolution of a fluid flow for smooth and finite energy initial data remains open, but his approach to the problem and his way of understanding it may inspire future generations of mathematicians, as most of his discoveries in topology and dynamics. For the time being, SULLIVAN will keep thinking about the problem, he never gives up.

Abel prize 2022

by PERE PASCUAL GAINZA (DMAT)
Received July 7th, 2022

The Norwegian Academy of Science and Letters awarded the **Abel prize** 2022 to DENNIS P. SULLIVAN "for his groundbreaking contributions to topology in the broadest sense, and in particular its algebraic, geometric and dynamical aspects". From the very beginning of his research career, initiated with his thesis work focused on the "Hauptvermutung", SULLIVAN has been recognised with numerous academic prizes, which point out the relevance of his work, of his results and of his deep insights.

SULLIVAN's research covers an ample variety of topics. We can mention: *geometric topology*, referred to below; *Klenian groups*, where he established an inspiring dictionary between Kleinian groups and rational dynamics based on the striking similarities that he discovered between both fields and where he collaborated with WILLIAM THURSTON generalising the Lipman Bers density conjecture; *conformal and quasiconformal maps*, extending the Atiyah-Singer index theorem for quasiconformal manifolds; or *qualitative theory of dynamical systems*, where he proved his celebrated non-wandering theorem for the iteration of a rational function of degree ≥ 2 on the Riemann sphere. He is also working in hydrodynamics and in quantum field theory.

A good introduction to the ideas and results of the first period of Sullivan's work can be found in his three influential talks at the International Congress of Mathematicians (ICM). In the ICM in Nice 1970, he presented "Galois theory in manifold theory at the primes", where he explains the main ideas on geometric topology to be discused below. In Vancouver 1974, he gave the talk entitled "Inside and outside manifolds", divided in two parts: the first one is about geometric topology, the outside part of the analysis of manifolds, while the second part is devoted to some results on dynamical systems defined on manifolds, the inside counterpart. The third lecture at an ICM, that of Berkeley 1986, with title "Quasiconformal, homeomorphisms in dynamics, topology and geometry", is a suvery of results on quasiconformal homeomorphisms. It is developed in four parts with a very different flavor, from his treatment of Feigenbaum numerical discoveries to the Atiyah-Singer theorem.

The first period of SULLIVAN's research focused on what he called *Geometric Topology*, devoted mainly to the invariants and classification of (simply connected) manifolds. In order to analyse the homotopy type of these manifolds, Sullivan decomposed them into pieces corresponding to localization and profinite completion at a prime number p and localization at 0, that is, taking rational models. He used the suggestive term *genotype of a space* to determine the rational and profinite types of a space, proving an equivalence of categories between the homotopy category of good spaces and the genotype category. This equivalence allowed him to decompose the analysis of the homotopy type of a space in different pieces: the profinite or algebraic part, which can be analyzed with algebraic techniques and in particular where he introduced the symmetry action of the absolute Galois group, and the rational (and real) part, where arithmetic and transcendental methods replace the algebraic ones.

Sullivan wrote a set of notes (MIT, 1970) which were not published at that time but circulated broadly between the specialists, entitled *Geometric Topology, Part I: Localization, periodicity and Galois symmetry*. In theses notes he presented also the complete classification of simply connected manifolds of dimension ≥ 5, announced at the Vancouver talk. The influence of the ideas presented in these notes was quoted by C.T.C. Wall in his book *Surgery on compact manifolds* (1971) where he writes "it is difficult to summarise Sullivan's work so briefly: the full philosophical exposition in (the notes) should be read". In 2005 Andrew Ranicki edited a revised version of these notes.

He used the profinite completion to prove the Adams conjecture in the late sixties, also proved by Daniel Quillen, which was one of the outstanding problems in topology at the time.

As for the rational side, Sullivan introduced in *Infinitesimal Computations in Topology* (1977) a commutative differential graded algebra (cdga) over $\mathbb{Q}$ associated to a triangulable space of finite type constructed by using polynomial differential forms with rational coefficients. This algebra satisfies a De Rham type theorem and encodes the rational homotopy type of the space. Moreover, Sullivan showed how to derive from it a minimal model, an equivalent cdga suitable for easy computations in some cases. He applied theses constructions to analyse Whitehead products, Kähler manifolds (in collaboration with P. Deligne, P. Griffiths, J. Morgan) or the space of closed curves on a manifold. This was the emergence of a new theory, Rational Homotopy Theory (RHT), which developed rapidly in the years to follow.

The influence of Sullivan's work at the UPC begun in the early eighties through the study of his paper on rational homotopy theory and his applications to Kähler manifolds. At that time there was a seminar on the topology of algebraic varieties directed by Vicenç Navarro Aznar where we were working on some cohomological and arithmetic aspects of algebraic varieties, essentially Mixed Hodge Structures (MHS) and Algebraic K-theory. As a byproduct, Navarro Aznar introduced MHS in the rational homotopy of singular varieties and on a variation of Hodge structures associated to the local systems coming from the rational type of the fibers of a proper smooth morphism. Also A. Roig developed a thesis focused on minimal models on different categories and its relation with fibrant/cofibrant models in Quillen's homotopical algebra. In 2005 in a joint work with F. Guillén, V. Navarro Aznar, A. Roig, we extended some of the results and techniques of Sullivan's RHT to prove the formality of the modular operad of the moduli spaces of curves of genus g with ℓ marked points, whose cohomological operad is related to complete cohomological field theories.

In 1999, in a collaboration with Moira Chas, Sullivan introduced a new topological invariant, a product on the homology of the space of free loops of a space, opening a new field of research, *String Topology*. Once more Sullivan changed the landscape of topology and drove it forwards.


Dennis Sullivan
Infinitesimal computations in topology
Publications mathématiques de l'I.H.É.S., tome 47 (1977), p. 269-331

MIT Professor Antonio Torralba, UPC Doctor *Honoris Causa*

by Miguel Ángel Barja (CFIS (Director), **IMTech** and CRM)
Received on June 14th, 2022

On March 11, 2022, it took place the Doctor Honoris Causa appointment ceremony by the Universitat Politècnica de Catalunya-Barcelona TECH (UPC) of Professor Antonio Torralba, head of the Faculty of Artificial Intelligence and Decision Making (AI+D) of the Electrical Engineering and Computer Science Department (EECS) at MIT. This appointment was made at the proposal of the Escola Tècnica Superior de Telecommunicacions de Barcelona (ETSETB), of which he is alumnus, and the Centre de Formació Interdisciplinària Superior (CFIS). For details, see the in Booklet of the awarding ceremony (versions in Catalan, Spanish and English).

Antonio Torralba is one of the greatest exponents and world's research leaders on Artificial Intelligence in Computer Vision. Deserving of many recognitions and awards such as the National Science Foundation Career Award in 2008, the J. K. Aggarwal Price of the International Association for Pattern Recognition in 2010 or the Amazon Research Award in 2016, before his current position he has also been MIT Director of the MIT-IBM Watson AI Lab and inaugural director of the cross-disciplinary initiative MIT Quest for Intelligence.

In his *laudatio*, Professor Ferran Marqués remarked that Antonio Torralba's research is especially relevant due to its interdisciplinarity, allowing a superior knowledge of vision from a deep knowledge of the psychophysical aspects and the understanding of the mechanisms of human perception. In his speech, the new doctor offered an account of the evolution of computer vision techniques in recent years, focusing on the relevant milestones, in many of which he has been one of the protagonists. He finally highlighted the current challenge of integrating vision with other senses, such as hearing or touch, which marks the most promising current lines of his research.

Professor Torralba has been one of the main precursors and endorsers of the CFIS International Mobility Program. Together with Professor Jaume Peraire, also recently appointed Doctor *Honoris Causa* by the UPC, he was one of the first to systematically welcome students from this university to carry out a research stay aimed at obtaining their Final Research Thesis. Since 2011 Professor Torralba has uninterruptedly welcomed students, many of whom he has then continued training himself or have obtained doctorates at the world's best universities.

Antonio Torralba's work has contributed to building trust and opening up new mobility positions in other departments over time. At the moment we have a unique International Mobility Program, with more than 100 positions, of which around 40 correspond to researchers at MIT, Harvard, Princeton, Berkeley, Caltech, Stanford, Columbia, New York, Toronto or NASA. As a result of this pioneering task of Professor Torralba, shared and subsequently expanded with other researchers, nowadays all the CFIS students spend a research semester abroad and among our alumni we have highly reputed researchers and promising young people in this and other areas who have made their academic careers in the world's leading research centers.

One of the fundamental challenges that our university, research and industrial system should address is *to create attractive conditions so that*, in the medium and long term, *a relevant part of this talent can return* and enrich the local scientific and technological ecosystem.

Noga Alon receives the 2022 Shaw Prize in Mathematical Sciences

by Oriol Serra (DMAT, **IMTech**)

Received June 15th, 2022

The laureate winners of the 2022 edition of the prestigious Shaw prize in Mathematics, rewarded with one million two hundred thousand $US, were announced on May 24th. The prize was awarded to Noga Alon (Princeton University) and Ehud Hrushovski (Oxford University) *for their remarkable contributions to discrete mathematics and model theory with interaction notably with algebraic geometry, topology and computer sciences*.

The news has been received with particular excitement by the mathematical and combinatorics community in Barcelona, which has had a strong interaction in the last decades with Noga Alon. He has visited Barcelona in many occasions, actively participating in several scientific meetings, with the *Societat Catalana de Matemàtiques* (SCM), the *Centre de Recerca Matemàtica* (CRM) and with the combinatorics community at *Universitat Politècnica de Catalunya* (UPC). The scientific collaboration has also resulted in close personal ties which make the recent award a particularly pleasant event.

The work of Noga Alon has had a profound impact on Discrete Mathematics and related areas. His seminal contributions include the development of ingenious techniques in Combinatorics, Graph Theory, and Theoretical Computer Science, and the solution of long standing open problems in these areas as well as in Additive Number Theory, Combinatorial Geometry and Information theory.

A brief description of his main achievements follows.

- Alon and his collaborators established the tight connection between the expansion properties of a graph and its spectral properties, and found numerous applications of expanders in Combinatorics and Theoretical Computer Science.

- He proved the Combinatorial Nullstellensatz, a powerful algebraic technique that yielded highly significant applications in Graph Theory, Combinatorics and Additive Number Theory, including an extension of the Four Color Theorem and generalizations of the Cauchy-Davenport Theorem.

- In joint work with Kleitman he settled a problem of Hadwiger and Debrunner in Combinatorial Geometry raised in 1957, proving a far reaching generalization of Helly's Theorem. The method has proven to be highly influential, and is described in most recent books and survey articles in the subject.

- He settled a problem of Shannon raised in 1956, proving the surprising fact that the Shannon capacity of a disjoint union of two channels can be much bigger than the sum of their capacities or even than any fixed power of this sum.

- He has played a major role in the development of probabilistic methods in combinatorics, and his book with Joel Spencer on the subject (*The Probabilistic Method*, Wiley, 4th Edition published in 2016) is the undisputed leading text in this central area.

- His results on derandomization —the process of converting randomized algorithms into deterministic ones— include the study of small sample spaces supporting nearly independent random variables, and the development (with R. Yuster and U. Zwick) of the Color Coding method, which has found applications in several other fields including the theory of Fixed Parameter Tractability and Bioinformatics.

- His joint work with Y. Matias and M. Szegedy initiated the study of streaming algorithms investigating which statistical properties of a stream of data can be sampled and estimated on the fly. This has literally created the new active area of streaming and sketching algorithms, and has numerous theoretical and practical applications.

- Alon and his collaborators developed an algorithmic version of Szemerédi's Regularity Lemma, discovered its connection to a classical inequality of Grothendieck, and used it to settle essentially all major open problems in the theory of Property Testing for dense graphs. This generated extensive research and played an important role in the subsequent development of the theory of convergent graph sequences by L. Lovász and his collaborators.

- Settling an old problem of V. G. Vizing he found an asymptotic formula for the minimum possible size of a graph that contains every graph on k vertices as an induced subgraph.

His discoveries have broken new grounds in Combinatorics, Graph Theory, Theoretical Computer Science, Combinatorial Number Theory and Combinatorial Geometry, introducing probabilistic, algebraic, combinatorial and topological techniques, and stimulating extensive research. His unique problem solving ability and the vast number of his original and ingenious contributions have changed the face of Discrete Mathematics, playing a major role in its transformation into a mature, well developed subject, and have had a tremendous influence on related areas as well.

IMTech members Ramon Codina and Eva Miranda awarded ICREA Academia distinctions

by Gemma Huguet (DMAT, IMTech and CRM)

Received June 20th, 2022

The Catalan Institution for Research and Advanced Studies (ICREA) has distinguished **IMTech** researchers Ramon Codina and Eva Miranda with the ICREA Academy 2021. Ramon Codina receives the award for the third time and Eva Miranda for the second time.

The ICREA Academia program was launched in 2008 with the aim of promoting and rewarding the research excellence of professors at public universities in Catalunya, who are in an active and expansive phase of their research career. Recognized researchers receive a research grant of 40,000 euros a year for a period of five years to promote their research. In the 2021 call, a total of seven UPC researchers have been recognized with ICREA Academia Prize.

Ramon Codina is full professor at the UPC Department of Civil and Environmental Engineering (DECA). He is member of **IMTech** and of the International Center for Numerical methods in Engineering (CIMNE). His research focuses on the development, analysis and implementation of methods for approximating the equations that govern problems in physics and engineering and, in particular, fluid mechanics. Specifically, the ICREA Academia grant will be used to develop robust scale models in complex systems, including fluid turbulence, and the application of artificial intelligence techniques to computational mechanics. This is his third ICREA Academia award: the previous ones were in 2011 and 2016.

Eva Miranda is full Professor at the Departament de Matemàtiques (DMAT/UPC and member of **IMTech** and of CRM). Her research deals with several aspects of Differential Geometry, Mathematical Physics and Dynamical Systems such as Symplectic and Poisson Geometry, Hamiltonian Dynamics, Group actions and Geometric Quantization. She will devote her ICREA Academia grant to study the interaction between singularities, symmetries and complex phenomena in geometry, dynamics and mathematical physics.

The research will be based on three pillars, which revolve around three open conjectures in mathematics: the singular Weinstein conjecture and its applications to celestial mechanics; the conjecture $[Q, R] = 0$ (quantization commutes with reduction) in singular symplectic manifolds; and the Navier-Stokes conjecture, one of the open issues on the Clay Foundation's millennium list. This is her second ICREA Academy, the first was awarded in 2016.

On the IMTech Colloquium 4/5/2022

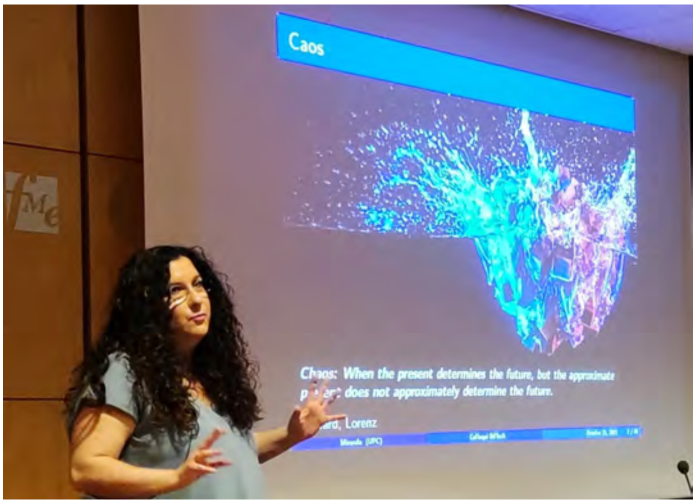
by Gemma Huguet (DMAT, IMTech and CRM)

Received June 20th, 2022

The speaker was Eva Miranda, who is Full Professor at the DMAT/UPC, distinguished with two consecutive ICREA Academia Awards (2016, 2021), member of **IMTech**, and of the CRM. She is the director of the Laboratory of Geometry and Dynamical Systems and leader of the group on Geometry of Varieties and Applications (GEOMVAP). She was recently awarded the Friedrich Wilhelm Bessel-Forschungspreis from the Alexander von Humboldt Foundation. She is an internationally renowned specialist in the areas of Differential Geometry, Mathematical Physics and Dynamical Systems. Her research deals with Symplectic and Poisson Geometry, Hamiltonian Dynamics, Group actions and Geometric Quantization.

Marta Casanellas, Eva Miranda and Gemma Huguet

The title of the lecture was *Indecibility, Complexity, and Chaos: From Cantor Sets to Turing Machines and Beyond*. In what follows we summarize the main points. The classical notion of chaos is characterized by sensitivity to initial conditions. A small change in these conditions causes the system to evolve very differently. As Edward Lorenz stated, the principle of chaos theory can be summarized as follows: "When the present determines the future, but the approximate present does not approximately determine the future." In particular, it is impossible to accurately predict weather because its initial state cannot be measured with sufficient accuracy. The slightest fluctuation, such as the beating of a butterfly's wings, can mean the difference between a drought and a flood at the other end of the planet. This phenomenon described by Lorenz himself is called the "butterfly effect".



Eva Miranda delivering her Colloquium

Cris Moore [4] found a new form of chaos that does not derive its unpredictability from the butterfly effect. With this notion of "complex chaos", Moore proved that certain chaotic systems are highly complex. Moore associates a Turing machine with its dynamical system using Cantor sets. As a result of the undecidability of the halting problem (Turing), the trajectories of the system are undecidable. Moore's constructions are 2-dimensional and were not initially associated with any "physical" system. Moore himself went further and asked if hydrodynamics was capable of calculations or if a water computer could be built. In 2017 Terence Tao took up this issue again motivated by an idea to construct a counterexample to the Navier-Stokes conjecture in the Clay list. His idea [5, 6] required the use of complete Turing-type initial conditions capable of simulating any Turing machine. In this talk Miranda explored these ideas and explained how to build a water computer [1]. In particular, in this paper they find fluid trajectories with undecidable paths. The construction uses contact geometry to associate a Reeb field with the Poincaré section of a disk application that extends the Moore construction. In this way a contact manifold of dimension 3 is obtained where the flow of the Reeb field is Turing complete. Using a mirror [3] that associates a Beltrami field with a Reeb field, this construction gives Euler fields in dimension 3 that have undecidable trajectories. This construction of a "water computer" makes Stanisław Lem's science fiction dream come true in the novel Solaris. But does it serve as a test machine to test counterexamples of the Navier-Stokes conjecture as Terence Tao dreamed?

The video of the talk is available at Video Zone.

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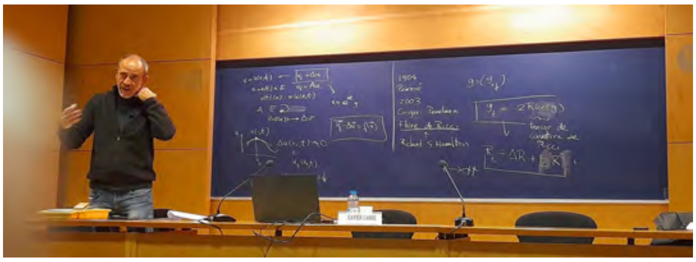
IMTech Panoramic Talks

by Gemma Huguet (DMAT, **IMTech** and CRM)

Received June 22th, 2022

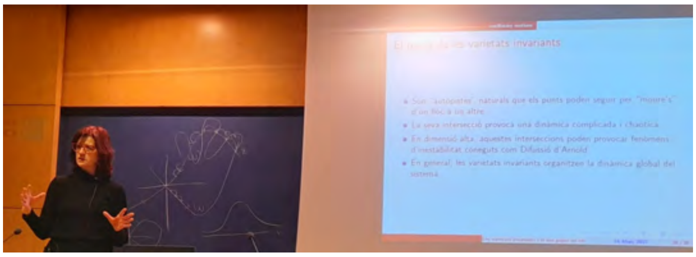
IMTech has launched a Cycle of Panoramic Talks, aimed at master and senior undergraduate students as well as young researchers, to present general overviews of current research topics given by top researchers in the field. The first three talks were given by **IMTech** researchers that are international leaders in the fields of partial differential equations, dynamical systems, and mathematical biology, respectively, and took place during the Spring semester 2021-22 term at the "Sala d'Actes de la Facultat de Matemàtiques i Estadística" (FME).

On February 23rd, 2022, Professor Xavier Cabré gave a talk entitled *PDEs: A heat equation proves the Poincaré conjecture*. Xavier Cabré is an ICREA Researcher and Full Professor of Applied Mathematics at UPC. He is a member of **IMTech** and CRM, and the leader of a Research group in PDEs and Applications, an area in which he is an internationally renowned specialist.



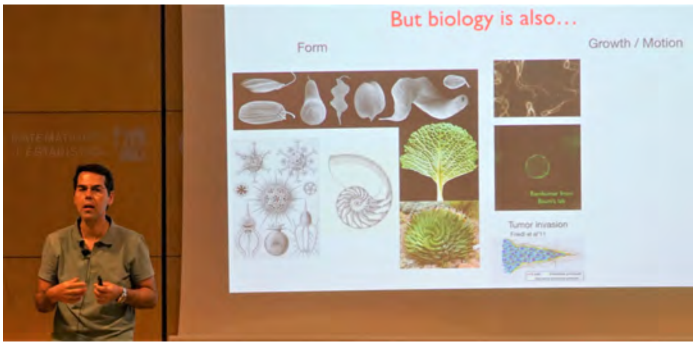
In the first part of the talk, he introduced the Laplacian through example models for heat and option prices in finance and presented an overview of different types of PDEs and their applications for modeling physical problems. In the second part, he explained the theory of Ricci flow developed by Richard Hamilton, and its role in the proof of the Poincaré conjecture by Grigori Perelman. The video of the talk is available at the Video Zone.

On March 16, 2022, Professor Tere M. Seara (UPC) gave a talk entitled *Invariant manifolds and their role in dynamical systems: from comet orbits to brain waves*. Tere M. Seara is Full Professor of Applied Mathematics at the UPC distinguished with an ICREA Academia Award (2017). She is member of **IMTech** and the CRM and the leader of the Research group Dynamical Systems at UPC. She is an internationally renowned specialist in Dynamical Systems, and, in particular, Hamiltonian Systems, exponentially small phenomena and Arnold diffusion.



In her talk, Professor Seara explained two problems, one in the field of celestial mechanics and another one in the neuroscience field, to motivate the role of invariant manifolds in the understanding of the global dynamics in dynamical systems. The first example was a model of neuronal activity showing depolarization waves that occur during migraine and ischemia. She showed that a heteroclinic connection can explain the existence of a travelling wave in the model. The second example was a restricted version of the 3-body problem that describes the position of 3 bodies that move by the effect of Newtonian gravitational forces and she showed that the existence of chaos in the system due to the splitting of invariant manifolds explains a type of movement known as "oscillatory" motion, where one of the bodies goes back and forth either approaching or moving away from the other two. The video of the talk is available at Video Zone.

On April 27, 2022, Professor Marino Arroyo (UPC) gave a talk entitled *Mathematical and computational modeling of living materials*. Marino Arroyo is Professor at UPC, a member of **IMTech**, and an associate researcher at CIMNE and at IBEC. He is member of the LaCàN Research group, where he leads the Research Program in Mechanics of soft and living interfaces. He is an internationally renowned specialist in mathematical modeling, mechanics and computations to understand the mechanics of materials and biological systems.



In his talk, Professor Arroyo presented an overview of the modeling challenges that appear in biology. He made the link between differential geometry and mechanics during growth processes at the cell, tissue, organ or organism level. He showed how through computational mechanics and mechanobiology, which integrates mechanics and biological structures and processes, the shape and functionality of organs can be predicted and explained. This includes gut crypts, brain folding, or sea shells morphogenesis. He also presented his recent work on how computational methods and variational principles allow quantifying mechanisms in cancer progression, cell budding, vesicle formation, or fracking in cells during lumen genesis. Video available at Video Zone.

IMTech plans to continue with the cycle of Panoramic Talks with two other talks during the Fall semester of the course 2022-23. One of the talks will be delivered by Professor Sebastià Xambó and will be devoted to *In search of effective models of Intelligence: Will Mathematics still have a role in that question?* A summary of the talk can be found here.

GLADS-2022

by Gemma Huguet (DMAT, **IMTech** and CRM)

Received July 20th, 2022

The conference GLADS-2022 (*Global and local aspects in dynamical systems: From Exponentially small phenomena to Instability*) was held at the IEC (Institut d'Estudis Catalans) on the week July 5-9 2022 and it was dedicated to Tere M. Seara on the occasion of her 60th birthday. She is Full Professor of Applied Mathematics at the UPC, distinguished with an ICREA Academia Award (2017), and member of the **IMTech** and the CRM. She is the leader of the Dynamical Systems group, has seminal contributions to relevant problems in the Dynamical Systems field in general and in Arnold Diffusion and exponentially small phenomena in particular.

The opening talk of the conference took place on June 27, also at the IEC, and was given by Professor Tere M. Seara herself. The talk (in Catalan) was open to a general audience and was entitled "Caos al Problema de Tres Cossos" (*Chaos in the Three Body Problem*). In the talk, she explained the types of asymptotic motions that can be found in the 3-body problem using tools from chaos theory.

The conference brought together nearly a hundred mathematicians from both the local and international community, including renowned leading experts in the field of Hamiltonian dynamics. It featured 30 guest talks, and more than a dozen posters. Speakers presented results on Arnold diffusion problems, KAM theory, celestial mechanics, splitting of separatrices, and chaos theory; topics, many of them, on which Professor Seara has worked throughout her career.

The conference dinner was held on Thursday July 8, with the presence of relatives and friends. There were speeches by collaborators and alumni, which served to talk about both Tere Seara's scientific career and her personal facet. All of them agreed to highlight her notable contributions to the field of dynamical systems, as well as her kind and optimistic nature, and her great involvement in student mentoring and leadership of a research group.

Scientific Committee

- Marie-Claude Arnaud,
- Amadeu Delshams,
- Vadim Kaloshin,
- Rafael de la Llave,
- Susanna Terracini.

Organizing Committee

- Inma Baldomà,
- Marcel Guàrdia,
- Gemma Huguet,
- Tomás Lázaro,
- Pau Martín,
- Carme Olivé,
- Jordi Villanueva.

The members of the Organizing Committee belong to the Dynamical Systems Group.

Gaudí: detail of the entrance grate to Park Güell

Reviews

Books

Commutative Algebra: Expository Papers Dedicated to David Eisenbud on the Occasion of his 75th Birthday, Springer 2021, xxii+889 pages. Edited by Irena Peeva. DE75
Reviewed by S. Xambó-Descamps.

Primarily, DE75 is a mathematical celebration of the 75th anniversary of David Eisenbud, who in that regard is "known for his work in algebra, algebraic geometry and symbolic computation" [1], and where essentially 'algebra' is to be understood as 'commutative algebra'. Precocious (he entered the University of Chicago at 16 and earned his PhD there at 23), consistently prolific in various fronts (as attested by his records on publications and collaborators, for instance in MathSciNet [2], and by the large number of his academic descendants, 36 reported in [3]), he has also been a wise and effective leader, as witnessed for example by his accomplishments as Director of the MSRI (1997-2007 and 2013-2022) and as President of the AMS (2002-2003). A sketchy story of all these aspects, and many others, is given in the frank and witty composition "Mostly Mathematical Fragments of Autobiography" by Eisenbud himself (DE75, ix-xxii). See also "Biosketch of David Eisenbud" (DE75, vii), the MacTutor biography [1], and the reflections [4] on the occasion of what looks as a major uplifting of the MSRI.

The editor of this volume, Irena Peeva, also edited a similar volume, DE65 (see the image, right-side, and [5]). Her Brandeis University PhD (*Free Resolutions*, 1995) was advised by D. Eisenbud. She has pioneered powerful methods in Commutative Algebra, as witnessed, for instance, by the vivid piece [6]. At present she is a Professor at Cornell Universtiy.

It is worth reproducing here the first two paragraphs of her Preface to DE65, as they nitidly convey the philosophy inspiring both volumes (the emphasis is not in the original):

> Commutative algebra is a vibrant field with activity on many fronts and *lively interactions with other fields such as algebraic geometry, algebraic combinatorics, computational algebra, invariant theory, mathematical physics, noncommutative algebra, representation theory, singularity theory, and subspace arrangements*. There have been *truly exciting recent developments both in core commutative algebra and at the interface with the above listed fields*.
>
> The main goal of this book is to showcase the field of commutative algebra in expository papers, *especially for the benefit of young mathematicians*. This book will aid the readers to broaden their background and gain deeper understanding of the current research in the area.

To illustrate the links of Commutative Algebra with other fields, even seemingly remote fields, we may look at the second paper in DE65: *Some Applications of Commutative Algebra to String Theory*. The author, Paul S. Aspinwall, is well-known in string theory, particularly for connections of this theory to algebraic geometry. For example, he is author of seven entries in the references of [7], an early treatise on the role of Algebraic Geometry in the Mirror Symmetry phenomenon. In the introduction of his paper we read what is the author's basic motivation: "Developments in recent years in computer packages for commutative algebra, such as Macaulay 2, mean that it is of great practical value if a problem can be translated into a question in commutative algebra", and the paper discusses three examples "where this happens".

Let us end with another special mention: the first paper in DE75, *Bernstein-Sato Polynomials in Commutative Algebra* (out of 37). We are glad to find that Josep Àlvarez Montaner (DMAT/UPC and **IMTech**) is one of its authors, together with Jack Jeffries and Luis Núñez-Betancourt. It is an extensive multi-faceted work that illustrates both the links of Commutative Algebra with several other domains and its expository character at its best, for there are a number of results that are improved or extended (see the second paragraph on page 2). One important facet of this commendable paper is the connection with works of Guillem Blanco, particularly his PhD thesis, summarized in NL02 (page 9), and his ▷ Research focus note on the solution of Yano's conjecture included in this issue.

Our congratulations to Irena Peeva, for her excellent editorial job; to all authors, for their contributions; and to David Eisenbud for his 75th birthday, for his long row of achievements, and for his candid disposition "to going back to the life of an ordinary professor at Berkeley, and to being back in the classroom".

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Papers

Diagonal Ramsey via effective quasirandomness, by ASHWIN SAH, to be published in the Duke Mathematical Journal (arXiv:2005.09251). Reviewed by MARC NOY.

The Ramsey number $R(k,k)$ is the smallest positive integer n such that every graph on n vertices contains either a complete subgraph on k vertices or an empty subgraph on k vertices. It was shown by FRANK RAMSEY in 1929 [4] that such a number always exists. Determining the order of magnitude of $R(k,k)$ is a main open problem in combinatorics. It is esay to show, as did PAUL ERDŐS and GEORGE SZEKERES [3], that $R(k+1,k+1) \leq \binom{2k}{k}$. This bound has been slowly improved over the years and the best current bound by DAVID CONLON [1] was $R(k+1,k+1) \leq k^{-c\log k/\log\log k}\binom{2k}{k}$ for some constant $c > 0$. The paper under review improves the bound to

$$R(k+1,k+1) \leq \exp(-c(\log k)^2)\binom{2k}{k},$$

thus removing the $\log\log k$ term. The proof relies on modern tools of combinatorics such as the notion of *quasirandomness* (loosely speaking, an infinite sequence of finite graphs is quasirandom if it shares the basic statistics of a random graph) and *graph limits* (continous objects that are limits in an appropriate sense of infinite sequences of finite graphs).

The best known lower bound is of order $2^{k/2}$, obtained by ERDŐS in a landmark paper introducing probabilistic methods in combinatorics [2]. This bound has been improved only in the lower order terms, hence there is a huge gap between the lower bound and the upper bound $\binom{2k}{k}$ whose order is $4^k/\sqrt{k}$. Even proving the existence of $\lim_{k\to\infty} R(k,k)^{1/k}$, which should be between $\sqrt{2}$ and 4, is an open problem that seems currently out of reach.

The achievement of ASHWIN SAH would have been impressive for any mathematician, but one should keep in mind that at the time he obtained his result he was an undergraduate at MIT just turned 21 (in 2021 he received the AMSMAA-SIAM Frank and Brennie Morgan Prize for Outstanding Research in Mathematics by an Undergraduate Student together with MEHTAAB SAWHNEY, his most frequent collaborator [6]). One cannot help thinking of FRANK RAMSEY, a great scholar in mathematics, philosophy and economics. RAMSEY published his now famous paper (it went rather unnoticed at the time) at the age of 26 and died of a liver illness the year after. For more on this exciting story we direct the reader to [5].

References

[1] D. Conlon, A new upper bound for diagonal Ramsey numbers, *Ann. of Math. (2)* 170 (2009), 941–960.

[2] [8] P. Erdős, Some remarks on the theory of graphs, *Bull. Amer. Math. Soc.* 53 (1947), 292–294.

[3] P. Erdős and G. Szekeres, A combinatorial problem in geometry, *Compositio Math.* 2 (1935), 463–470.

[4] F. P. Ramsey, On a Problem of Formal Logic, *Proc. London Math. Soc.* (2) 30 (1929), 264–286.

[5] Quantamagazine article

[6] Morgan prize 2021

On a density conjecture about unit fractions, by THOMAS BLOOM, [2]. Reviewed by JUANJO RUÉ.

An *Egyptian fraction* is a sum of positive (usually) distinct unit fractions. The famous Rhind papyrus, dated to around 1650 BC contains a table of representations of $2/n$ as Egyptian fractions for odd n between 5 and 101.

In this context, ERDŐS and RONALD GRAHAM conjectured in [3] that for any colouring $c : \mathbb{N} \to \{1,\dots,k\}$ of the integers (where k is arbitrary but finite), there exists a set $S \subseteq \mathbb{N}$ whose elements receive the same colour such that

$$\sum_{n\in S} \frac{1}{n} = 1.$$

This conjecture falls inside the realm of *Ramsey Theory*, and was affirmatively proven by ERNIE CROOT on 2003 in the *Annals of Mathematics* paper [1].

Once a Ramsey statement is proven, the next question (much harder) is the quantitative version. In our case: is it true that any set $S \subseteq \mathbb{N}$ with *positive density* contains a subset S' such that $\sum_{n\in S'} \frac{1}{n} = 1$? Observe that such a quantitative version trivially implies the corresponding Ramsey result. This situation may be compared with Van der Waerden Theorem on arithmetic progressions (a result on Ramsey Theory) with its corresponding quantitative version, the celebrated Szemerédi's Theorem.

Very recently, THOMAS BLOOM had solved this problem on the reviewed paper [2], getting the quantitative version of Erdős-Graham conjecture. Compared with the most natural way to attack the problem (analysis of exponential sums) the approach of BLOOM (building on the original Croot's proof) is based on using combinatorial and elementary number theoretical ideas in order to find sets with reciprocals that add up to smaller constituent fractions, and then using these as building blocks to get to the desired result.

References

[1] E. Croot, On a coloring conjecture about unit fractions, *Annals of Mathematics*, 157 (2) (2003): p.545-556.

[2] T. Bloom, On a density conjecture about unit fractions, submitted (arXiv pdf).

[3] P. Erdős, R. Graham, Old and new problems and results in combinatorial number theory, *L'Enseignement Mathématique* (1980): p.30-44.

Quotations

"Mathematics only exists in a living community of mathematicians that spreads understanding and breaths life into ideas both old and new. The real satisfaction from mathematics is in learning from others and sharing with others. All of us have clear understanding of a few things and murky concepts of many more. There is no way to run out of ideas in need of clarification. The question of who is the first person to ever set foot on some square meter of land is really secondary. Revolutionary change does matter, but revolutions are few, and they are not self-sustaining —they depend very heavily on the community of mathematicians." William Thurston (1946-2012.08.21). From an answer to a question in MathOverflow (2010).

"The outcome is simply a question of time, but time will come when the machines will hold supremacy over the world and its people is what no person of a truly philosophic mind can for a moment question," Samuel Butler (from the essay *Darwin among the Machines*, 1863).

"… and all life long my instinct has been to abandon anything for which I have no talent; tennis, golf, dancing, sailing, all have been abandoned, and perhaps it is desperation which keeps me writing…" Graham Greene (from *A Sort of Life*, 1971).

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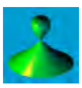
The *Dingdong* image in the cover, from Herwig Hauser's Gallery of Singular Algebraic Surfaces, is one of those included in the Imgaginary exhibits.