

INSTITUTO DE CIENCIAS MATEMÁTICAS

annual report 2021













ICMAT Annual report 2021



The Instituto of Mathematical Sciences is a joint research of the Consejo Superior de Investigaciones Cientificas (CSIC, Spanish National Research Council) and three Madrid universities: Universidad Autónoma de Madrid (UAM), Universidad Carlos III de Madrid (UC3M) and Universidad Complutense de Madrid (UCM). The ICMAT is a leading international research center in mathematics, recognized by three consecutive <u>Severo Ochoa Excellence Awards</u>.

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1. Introduction

2021, another difficult year

José María Martell, director of the ICMAT (from January 2020 until July 2022).

In 2020, the ICMAT received the third consecutive Severo Ochoa excellence award, which allowed the Institute to continue and expand the outstanding level of scientific momentum obtained with the last two distinctions. However, the persistence of the COVID-19 pandemic in 2021 has represented a significant hurdle for all scientific endeavor, especially for face-to-face events. We have worked hard to keep producing research results of the highest level, and also to maintain our links with the outside mathematical world, mainly through online activities. This shows that ICMAT is a healthy research institution, and allows to be optimistic about the coming years, in which we hope to be able to return to normality, organizing large conferences, research schools, trimesters, and seminars, and inviting leading mathematicians to visit the institute, to start or continue fruitful research collaborations. Thanks to the combined effort of the researchers and administrative staff of the ICMAT, I have no doubt that we will succeed in this challenge.



José María Martell, director of the ICMAT (2020-2022)



2. The ICMAT in figures

Scientific activities



Publications



Personnel



Distribution by gender



ICMAT Funding 2021

Projects



3. Personnel

3.1. Research groups

At present, the ICMAT is structured around three main research groups:

- GROUP A: <u>Algebra and geometry</u>
- GROUP B: <u>Mathematical analysis and differential equations</u>
- GROUP C: Applied mathematics

GROUP A: Algebra and geometry

The group conducts research in a broad variety of topics, in the areas of abstract algebra (group theory, commutative algebra), algebraic geometry (arithmetic geometry, number theory, moduli spaces of bundles), differential geometry (geometric analysis, geometric mechanics, dynamical systems and the geometry of PDEs) and topology (topological fluid dynamics, symplectic and contact topology, low-dimensional topology).

As such, our research is naturally interdisciplinary, fostering an important level of cross-fertilization between the different areas. In addition, a number of the themes we study find their motivation in ideas stemming from physics, such as special metrics, gauge theories and their algebro-geometric counterparts.

The main research lines may be grouped into the following four general directions:

- Algebraic geometry and mathematical physics: The research of this line is devoted to the study of moduli spaces of vector bundles and related objects, and their interplay with various algebraic and geometric structures, involving techniques from algebraic geometry, differential geometry, topology, Lie theory, geometric analysis and theoretical physics.
- Differential geometry, symplectic geometry and geometric mechanics: The research of this line centers on differential and contact topology, differential and Riemannian geometry, geometric mechanics with applications to control theory, dynamical systems and the geometry of PDEs.
- **Group theory:** This line includes several areas of group theory with applications to other fields, such as ring theory, topology, dynamics, and logic. Connecting threads of this line are the approximation of infinite groups by finite structures, and the study of groups through their actions on non-positively curved spaces.
- Arithmetic geometry: The research in this line is devoted to
 problems at the core of arithmetic geometry, like the equivariant Tamagawa number conjecture or the development
 of Arakelov geometry, as well as its interplay with related
 fields like complex and non-Archimedean analysis, algebraic geometry and even theoretical physics.

The following researchers are part of this group:

Faculty

- Luis Álvarez
- Yago Antolín
- Javier Aramayona

- Nuno Freitas
- Ana Bravo
- José Ignacio Burgos
- Manuel de León
- José Francisco Fernando
- Oscar Segundo García-Prada
- Tomás Luis Gómez
- Luis Guijarro
- Andrei Jaikin
- Ignacio Luengo
- David Martín
- Daniel Peralta
- Francisco Presas
- Piergiulio Tempesta

Members

- Mathieu Ballandras
- Benjamin Bode
- Caterina Campagnolo
- Federico Cantero
- Eva Elduque
- Dominik Francoeur
- Mario García
- Alejandra Garrido
- José Ángel González
- Luis Hernández
- King Leung Lee
- Daniel Macías
- Leo Margolis
- Alan McLeay
- Beatriz Molina
- Alberto Navarro
- Beatriz Pascual
- Arpan Saha
- Amna Shaddad
- Carolina Vallejo

Doctoral students

- Jesús Aguado
- Guillermo Barajas
- Jan Boschheidgen
- Javier Casado
- Bilson Castro
- Iván Chércoles
- Andoni de Arriba
- Rodrigo Alonso de Pool
- Celia del Buey
- Dahyana Eugen Farias



- Guillermo Gallego
- Raúl González
- Jacob Goodman
- Manuel Lainz
- Xabier Legaspi
- Asier López
- Enrique Martínez
- Francisco Javier Martínez
- Daniel Martínez
- Manuel Mellado
- Henrique Souza
- Álvaro Rodríguez
- Álvaro Romaniega
- Guillermo Sánchez
- Roberto Téllez
- Didac Violan
- Wei Zhou

Associated members

- María Barbero
- Juan Carlos Marrero
- Eva Miranda
- Edith Padrón
- Orlando Villamayor

GROUP B: Mathematical analysis and differential equations

Mathematical analysis and partial differential equations are very active, deeply interrelated fields of research with a preponderant position within the mathematical sciences. This line deals with fundamental problems in the fields of harmonic analysis, partial differential equations, geometric group theory, functional analysis, geometric measure theory, operator algebra, differential geometry and probability, and has been awarded with a total of seven ERC grants.

The group is formed by two sublines:

- Mathematical analysis: This subline focuses on classical problems around the Kakeya conjecture and Bochner-Riesz multipliers, the Schrödinger and wave equations, elliptic PDE in rough domains and connections with geometric measure theory, harmonic analysis and geometric group theory for nonamenable groups, classical and abstract Calderón-Zygmund theory and problems around the invariant subspace problem. Other fields such as operator theory, geometry of Banach spaces, complex analysis, quantum probability and analytic number theory are also well represented.
- Differential equations and applications: This subline studies differential equations arising in fluid mechanics, spectral theory, mathematical physics and mathematical biology. This is an interdisciplinary subject, with significant applications to engineering, biology and physics.

Master students

- Alberto Angurel
- Sergio Domingo
- Juan Manso
- Javier Peñafiel
- Pablo Sánchez
- José Torrente

In 2021, this group organised the following activities:

- Group theory Seminar
- Number theory Seminar
- Geometry Seminar
- Geometry, mechanics and control Seminar
- Commutative algebra, algebraic and arithmetic geometry Seminar
- Research programme on moduli spaces
 - Reading seminar on vertex algebras
- Groups in Madrid
- Thematic programme: L2-invariants and their analogues in positive characteristic

The following CSIC research groups are involved in Group A:

- <u>GROUP 4: Algebraic geometry and mathematical physics</u>
- <u>GROUP 5: Differential geometry and geometric mechanics</u>
- <u>GROUP 8: Group theory</u>
- GROUP 9: Number theory

The following researchers are part of this group:

Faculty

- José María Arrieta
- Matteo Bonforte
- Florentino Borondo
- Ángel Castro
- Fernando Chamizo
- Diego Córdoba
- Alberto Enciso
- Daniel Faraco
- Eva Gallardo
- María del Mar González
- Manuel Mañas
- José María Martell
- Jesús Munárriz
- Rafael Orive
- Javier Parcet
- Ana Primo
- Fernando Quirós
- Aníbal Rodríguez
- Keith Rogers
- Alberto Ruiz
- Pedro Tradacete
- Dmitry Yakubovich

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Members

- Siddhant Agrawal
- Davide Barbieri
- Glenier Bello
- Pablo Candela
- Mingming Cao
- Hon to Hardy Chan
- José Manuel Conde
- Elena di Iorio
- Antonio Jesús Fernández
- Wadim Gerner
- Adrián González
- Nastasia Grubic
- Matthew Hernández
- Salvador López
- Teresa Elvira Luque
- María Medina
- Javier Montes
- Neel Janak Patel
- Javier Ramos
- Guillermo Rey
- Tomás Sanz
- Daniel Seco
- Fan Zheng

Doctoral students

- Antonio Ismael Cano
- Víctor Cañulef
- David de Hevia
- Laia Domingo
- Joaquín Domínguez

GROUP C: Applied mathematics

This research group works to develop the mathematical foundations and models needed to deal with the main new societal challenges, with a focus on data science, machine learning and quantum technologies. It is divided in the following research lines:

- Mathematics of quantum information theory: Quantum technologies are nowadays one of the most promising technologies for the near future. They exploit quantum effects to develop new techniques in fields like cryptography, metrology, material science, pharmacology and many others, which have the potential to go far beyond the current (classical) state of the art. The group "Mathematics and quantum information" at ICMAT works in a wide variety of mathematical problems which are motivated by quantum technologies. Some of the topics considered in this line are: condense matter and many body systems, quantum control, foundational aspects of quantum mechanics and the theory of operator algebras.
- Machine learning and data science: Machine learning and data science are disciplines that are at the core of many current significant societal developments. Embedded in the disciplines of statistics, probability, optimization and algebra, with strong support from computer science developments, this line emphasizes, methodological developments focusing on providing efficient Bayesian approaches to the treatment of large scale inference and prediction problems and methods to deal with the presence of adver-

- Alba Dolores García
- Francisco Javier González
- Pablo Hidalgo
- Peio Ibarrondo
- Luis Martínez
- Jorge Pérez
- Elena Salguero
- Omar Sánchez
- Eduardo Tablate

Associated members:

- Antonio Córdoba
- Alberto Ruiz

Master students:

- Antonio Álvarez
- Fernando Ballesta
- Enrique García
- Jorge Ruiz

In 2021, this group organised the following activities:

- Analysis and applications Seminar
- PDE's and fluid mechanics Seminar
- Number theory Seminar
- Machine Learning Seminar
- Study Group on Euler Systems

The following CSIC research groups are involved in Group B:

- GROUP 1: Mathematical analysis
- GROUP 2: Differential equations and applications
- GROUP 9: Number theory

saries ready to perturb the data and structure in a problem though adversarial risk analysis and adversarial machine learning. Moreover, it also emphasizes dealing with complex applied problems mainly in the areas of security and cybersecurity, with the aid of its DataLab.

 Mathematical modelling and simulation: This covers a wide spectrum ranging from the multidisciplinary mathematical approach to the problems, with emphasis in numerical computation, to the promotion of applications by means of collaborations with other departments such as engineering, biology, physics and earth sciences all around the world. Research include topics such as microfluidics modelling and technological applications, geophysical fluid dynamics, etc.

The following researchers are part of this group:

Faculty

- Nuria Campillo (Centro de Investigaciones Biológicas Margarita Salas – ICMAT)
- Marco Antonio Fontelos
- Alberto Ibort
- Fernando Lledó
- Carlos PalazuelosDavid Pérez
- David Perez
 Carlos Rascón
- David Ríos
- Ignacio Villanueva



Members

- Makrina Agaoglou •
- Jorge Castillejos
- Fabio di Cosmo
- Daniel García .
- César Byron Guevara
- Tamara X. J. Kohler •
- Angelo Lucia •
- Roi Naveiro .
- Juan Manuel Pérez ٠
- Alejandro Pozas-Kerstjens
- Simón Rodríguez

Doctoral students

- José Manuel Camacho .
- Guillermo García Sánchez
- José Ramón Pareja
- Alberto Ruiz de Alarcón

Master students:

Gustavo Rodríguez •

In 21, this group organised the following activities:

- Applied mathematics Seminar •
- DataLab Seminar
- Q-Math Seminar
- Machine Learning Seminar
- Modelling in microfluidics and technological applications •
- Geophysical fluid dynamics
- Stochastic and analytical methods in applied mathematics

The following CSIC research groups are involved in Group C:

- GROUP 3: Statistics, probability and operations research (SPOR)
- GROUP 6: Mathematics of quantum information: foundations and applications

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GROUP 7: Mathematical modelling and simulation

3.2. Executive team and board



ICMAT Committees

- Scientific Committee
 - Chairs: Alberto Enciso, José María Martell
 - Members: Diego Córdoba, Oscar García-Prada, Andrei Jaikin, David Pérez, David Ríos
 - Support staff: Mónica Castresana
- Committee of Internal Institutional Relations
 - Chair: Fernando Quirós
 - Members: Luis Álvarez-Cónsul, Eva Gallardo, Fernando Lledó
 - Support staff: Esther Fuentes

Committee of External Institutional Relations

- Members: José María Arrieta, Daniel Peralta, José María Martell
- Support staff: Mónica Castresana

• Mathematical Culture Unit

- Chairs: David Martín, Javier Aramayona
- Coordinator: Ágata Timón
- Members: José María Martell, Alberto Enciso, Daniel Peralta, Fernando Quirós
- Support staff: Laura Moreno Iraola

Equality Committee

- Chair: Ana Bravo
- Coordinator: Ágata Timón
- Members: Javier Aramayona, Eva Gallardo, David Martín
- External Members: Marta Macho-Stadler (EHU), Catalina Martínez (IPP)
- Support staff: Laura Moreno Iraola

Committee of Internal Regulations

- Chair: Tomás Gómez
- Members: Luis Guijarro, Ignacio Villanueva, Alberto Ibort
- Support staff: Esther Fuentes

Postgraduate Committee

- Chairs: Ángel Castro, Pedro Tradacete
- Members: José Francisco Fernando, Ana Primo, Daniel Seco
- Support staff: Esther Ruiz

Library Committee

- Members: José Manuel Conde, Mario García
- Support staff: Teresa Ruiz

ICT Committee

- Members: Davide Barbieri, Ignacio Luengo, Daniel Macías
- Support staff: Eduardo de Córdoba, Alfonso Núñez





3.3. ICMAT External Scientific Advisory Committee



From left to right and top to bottom, Martin R. Bridson (University of Oxford), Luis Caffarelli (Texas State University), Peter Constantin (Princeton University), Frances Kirwan (University of Oxford), Jill Pipher (Brown University), Antonio Ros (Universidad de Granada), Claire Voisin (College de France) y Shing-Tung Yau (Harvard University).

The ICMAT External Scientific Advisory Committee, approved by the Center's Board of Directors at the end of 2019, is composed of eight prestigious international mathematicians:

Martin R. Bridson (Isle of Man, 1964) is Whitehead Professor of Pure Mathematics at Oxford, and the current President of the Clay Mathematics Institute. Bridson is internationally renowned for his contributions to group theory and low-dimensional topology, where his results about geometric and algorithmic properties of groups have been deeply influential. Together with Haefliger, he authored the monograph "Metric Spaces of Non-Positive Curvature" which, with nearly 2000 citations, has become a keystone of the field of geometric group theory. Bridson obtained his PhD in 1991 at Cornell, and subsequently held positions at Princeton, Geneva, and Imperial, before joining Oxford in 2007. He has been a recipient of the LMS Whitehead Prize (1999), the Wolfson Research Merit Award of the Royal Society (2012), and the Steele Prize of the American Mathematical Society (2020). He was an Invited Lecturer at the 2006 International Congress of Mathematicians, and is a Fellow of the Royal Society since 2016.

Luis Caffarelli (Argentina, 1948) is Sid W. Richardson Foundation Regents Chair in Mathematics No. 1 Professor of Mathematics at the University of Texas at Austin. Caffarelli is a well- recognized expert in partial differential equations and free boundary problems, where he has had a countless number of breakthrough achievements. Caffarelli received his Ph.D. from the Universidad de Buenos Aires (Argentina) and after that, he was a postdoc at the University of Minnesota where he eventually became Professor. He has also held professorial positions at the Courant Institute of Mathematical Sciences, the University of Chicago, and the Institute for Advanced Study in Princeton. Caffarelli has been recognized with several prestigious awards, including the Bôcher Memorial Prize (1984), from the American Mathematical Society for "his deep and fundamental work in nonlinear partial differential equations, in particular his work on free boundary problems, vortex theory and regularity theory;" the Rolf Schock Prize (2005) from the Royal Swedish Academy of Sciences, the Wolf Prize in Mathematics (2012) from the Wolf Foundation, and the Shaw Prize in Mathematics (2018) from the Shaw Prize Foundation for "his groundbreaking work on partial differential equations, including creating a theory of regularity for nonlinear equations such as the Monge-Ampère equation, and free-boundary problems such as the obstacle problem, work that has influenced a whole generation of researchers in the field." Caffarelli has also been awarded Doctor Honoris Causa from the École Normale Supérieure (Paris, France), the University of Notre Dame (USA), the Universidad Autónoma de Madrid (Spain), and several universities in Argentina such as the Universidad de La Plata or the Universidad de Buenos Aires. Caffarelli gave a plenary lecture at the 2002 International Congress of Mathematicians and was an invited speaker at the 1983 edition.

Peter Constantin (Romania, 1951) is the John von Neumann Professor of Mathematics and Applied and Computational Mathematics and serves as director of the Program in Applied and Computational Mathematics at Princeton University since 2012. He has also been a Louis Block Professor and Louis Block Distinguished Service Professor at the University of Chicago (2005-2011). He is an ISI Highly Cited Researcher and a Fellow of the American Academy of Arts and Sciences. Furthermore, he has been invited to give talks at the International Congress of Mathematical Physics (Paris 1994), the International Congress of Mathematicians (Zurich 1994) and the International Congress of Industrial and Applied Mathematics (Edinburgh 1999). **Frances Kirwan** (UK, 1959) is a professor at the Mathematical Institute of Oxford University (United Kingdom). She was the President of the London Mathematical Society from 2003 to 2005. Her work on algebraic geometry and symplectic geometry has earned her numerous awards, including the Whitehead Prize (1989) and the Whitehead Senior Prize (2013) from the London Mathematical Society, as well as an OBE in 2014. Furthermore, she is a Fellow of the Royal Society, since 2001, has held an EPS-RC Senior Research Fellowship from 2005 to 2010, is a Fellow of the American Mathematical Society since 2012, and is a member of the European Academy.

Jill Pipher (USA, 1955) is Vice President for Research at Brown University and Elisha Benjamin Andrews Professor of Mathematics. She is currently the president of the American Mathematical Society, was the president of the Association of Women in Mathematics (AWM, 2011-2013) and is a founding director of the Institute for Computational and Experimental Research in Mathematics, an NSF mathematical institute in Providence, USA. Pipher obtained her Ph.D. in Mathematics from the University of California at Los Angeles in 1985. After that, she was L. E. Dickson Instructor at the University of Chicago. Pipher has obtained breakthrough results in harmonic analysis and partial differential equations. She has also worked in cryptography; she co-founded NTRU Cryptosystems, Inc., and holds four patents related to encryption algorithms. Pipher is an inaugural fellow of the American Mathematical Society (2012) and was selected as a fellow of the Association for Women in Mathematics in the inaugural class in 2017. In 2019 she was named a SIAM Fellow "for her profound contributions in analysis and partial differential equations, groundbreaking work in public key cryptography, and outstanding scientific leadership." Pipher was an invited speaker at the 2014 International Congress of Mathematicians.

Antonio Ros (France, 1957) is Professor at the Department of Geometry and Topology in the Universidad de Granada (Spain). He is a member of the School of Geometrical Analysis in Granada, whose quality and scientific impact is internationally recognized. His research interests concern differential geometry, analysis and focus in the theory of minimal surfaces and isoperimetric problems. Among his results, one can highlight the celebrated proof of the double bubble conjecture (joint with Hutchings, Morgan and Ritoré) and more recently, together with Meeks and Pérez, he has completed the classification of properly embedded minimal planar domains in euclidean 3-space. Both results were published in Annals of Mathematics. Antonio Ros was an invited speaker at the 2006 International Congress of Mathematicians.

Claire Voisin (France, 1962) holds the chair of Algebraic Geometry at the Collège de France. She obtained her Ph.D. from the Université Paris-Sud XI-Orsay. She has worked as a CNRS researcher at the Institut de Mathématiques de Jussieu and the Ecole Polytechnique before joining her current institution in 2016. Voisin has been awarded the European Mathematical Society Prize (1992), the Clay Research Award (2008) for "her disproof of the Kodaira conjecture," the Ruth Lyttle Satter Prize in Mathematics (2007) "for her deep contributions to algebraic geometry, and in particular for her recent solutions of two long-standing open problems: the Kodaira problem and Green's conjecture." She has also received the Shaw Prize in Mathematics (2017) from the Shaw Prize Foundation and received the Gold medal of the French National Centre for Scientific Research (2016), the highest scientific research award in France. Voisin was an invited speaker at the 1994 and 2010 editions of the International Congress of Mathematicians.

Shing-Tung Yau (China, 1949) is the William Caspar Graustein Professor of Mathematics at Harvard University. He got his Ph.D. from the University of California-Berkeley and after that, he was a member of the Institute for Advanced Study at Princeton, Stony Brook University, Stanford University, and Univeristy of Califiornia - San Diego. Yau was awarded the Fields Medal in 1982 "for making contributions in differential equations, also to the Calabi conjecture in algebraic geometry, to the positive mass conjecture of general relativity theory, and to real and complex Monge- Ampère equations." Yau has also obtained the Wolf Prize in Mathematics (2010) for "his work in geometric analysis and mathematical physics," the United States National Medal of Science (1997), and the Humboldt Research Award (1991) from the Alexander von Humboldt Foundation in Germany. Yau was also a plenary speaker at the 1978 International Congress of Mathematicians.

From left to right and top to bottom, Martin R. Bridson (University of Oxford), Luis Caffarelli (Texas State University), Peter Constantin (Princeton University), Frances Kirwan (University of Oxford), Jill Pipher (Brown University), Antonio Ros (Universidad de Granada), Claire Voisin (College de France) y Shing-Tung Yau (Harvard University).

3.4. Support technicians

Thanks to the funding from the Severo Ochoa award, the ICMAT continues to have a technical and support team, which allows the Institute to develop its own internationalization, knowledge transfer, outreach and gender programs, among others.

Administrative Office:

- Esther Ruiz
- Teresa Ruiz

ICT Office

- Eduardo de Córdoba
- Alfonso Núñez

Mahematical Culture Unit

- Laura Moreno
- Ágata Timón

Severo Ochoa Office

Esther Fuentes

Project Management Office

- Mónica Castresana (International projects)
- Marc Cornadó (National projects)
- Esther Ruiz (National projects)

AXA Office

• Marta Sanz



4. Scientific results

In 2021, the scientific production of ICMAT researchers has reached 161 publications. According to the Journal of Citations Reports Web of Science, 26 publications appear in D1 (first decile) and 64 in Q1 (first quartile) if one uses the Article Influence Score; with respect to Impact Factor, 62 are in D1 and 111 are in Q1. Similarly, Elsevier CiteScore gives 25 D1 and 82 Q1.

Here are some scientific reviews of these articles:

"Mixing solutions for the Muskat Problem"

Authors: Ángel Castro (ICMAT-CSIC); Diego Córdoba (ICMAT-CSIC) and Daniel Faraco (ICMAT-UAM)

Source: Inventiones Mathematicae vol. 226, pages 251-348

Date of publication: 5 May 2021

<u>Link</u>

Review:

In fluid mechanics, one is typically interested in describing the evolution of a scalar transported by a fluid, where the fluid and the velocity and the fluid are coupled. In most of the classical texts, in physics and mathematics, one computes the linearized problem around some stationary solution and declares the problem stable or unstable depending on the sign of the spectrum. In the linearly stable case, deep research amounts to show that the non-linear equation is indeed well posed and in the best scenario there is a global in time solution. In the unstable situation, classical tools in analysis and PDE fail and either one finds explicit solutions in particular situations, performs experiments or run simulations.

In this work, the authors present a very robust method to construct weak solutions to unstable problems by combining the convex integration method of De Lellis and Székelyhidi with the contour dynamics evolution.

The paper is devoted to the Muskat problem, the evolution of a scalar through a porous media, were the effect of the porous and the gravitiy is represented by the well-known Darcy's law. In experiments going back to Saffman and Taylor, and brought back to the mathematical community by F. Otto, one sees the presence of a so-called mixing zone where the two fluids mix stochastically.

Their method describes such a mixing zone as an envelope of a curve, whose evolution is dictated by an average of the, by now classical, Muskat operator. The double average regularizes the operator for positive time but blows up when times goes to zero. In order to circumvent that difficulty, they create a semi classical calculus for non-smooth operator understanding time as the small parameter playing the role of the Planck constant.

In simulations, one sees different pointwise solutions at every sample, a phenomenon that physicists have baptised as spontaneous stochasticity and the strong butterfly effect. However observable quantities are expected to behave classically. Thus deterministic models are consistent with stochastic ones.

The method described in the paper does not only yield the expected weath of non-unique weak solutions, but predicts the evolution of macroscopical quantities such as size and shape of the mixing zone. Non trivial elaboration of these ideas has been use to deal with vortex sheet type problems or partially unstable situations. "Carleman estimates with sharp weights and boundary observability for wave operators with critically singular potentials"

Authors: Alberto Enciso (ICMAT-CSIC), Arick Shao and Bruno Vergara

Source: Journal of the European Mathematical Society vol. 23, no. 10

Date of publication: 9 June 2021

<u>Link</u>

Review:

Carleman estimates are estimates for differential operators which involve exponential weights of arbitrarily high strength. Yet they are uniform with respect to the strength parameter, they are a powerful tool to establish quantitative uniqueness results for differential equations. Furthermore, they have found a wealth of applications including the study of inverse problems, observability and controllability properties, and the analysis of eigenvalues embedded in the continuous spectrum.

The objective in this paper is to derive Carleman estimates for wave operators with critically singular potentials, that is, with potentials that scale like the principal part of the operator. More specifically, the researchers are interested in the case of potentials that diverge as an inverse square on a convex hypersurface. For simplicity, they consider the simplest case where the aforementioned hypersurface is the unit sphere.

The key properties of the Carleman estimates they seek is that they are "sharp" and "global". We say they are sharp, in that the weights that appear capture both the optimal decay rate of the solutions near the boundary (which is nontrivial and depends on the strength of the singular potential), as well as the natural energy that appears in the well-posedness theory for the equation. This property is not only desirable but also essential for applications such as boundary observability. By "global", we mean that the Carleman estimate does not only involve the behavior of (suitably cut-off) functions near the hypersurface, but also capture their behavior inside the domain bounded by the hypersurface (in this case, the unit ball). This enables the authors to prove not only a unique continuation result, but also an interesting boundary observability property for the associated wave equations.

Without getting into unnecessary technicalities, the proof is based around three key ingredients: the choice of a novel Carleman weight with rather singular derivatives on the boundary, a generalization of the classical Morawetz inequality that allows for inverse-square singularities, and the systematic use of derivative operations adapted to the potential.

"Constructing Turing complete Euler flows in dimension 3"

Authors: Robert Cardona, Eva Miranda, Daniel Peralta-Salas (ICMAT-CSIC) and Francisco Presas (ICMAT-CSIC)

Source: Proceedings of the National Academy of Sciences vol. 118, no. 19

Date of publication: 11 May 2021

<u>Link</u>

Review:

The computational power of a physical system is measured in terms of its ability to simulate a universal Turing machine. We recall that a Turing machine is a mathematical model of a theoretical device manipulating a set of symbols on a strip of tape with some specific rules; any computer algorithm can be described in terms of Turing machines. During the last decades, several physical processes have been shown to exhibit such Turing completeness, from ray tracing problems in 3D optical systems to neural networks or non-abelian topological quantum field theories. Additionally, Turing completeness of a physical system is intimately related to the undecidability of its evolution, which can be understood as an emergence of complexity in physics totally different from the chaotic behavior.

In contrast, the computational power of fluid dynamics is much less understood. In this direction, Chris Moore asked in 1991 if hydrodynamics is capable of performing computations, i.e., can a fluid ow simulate a universal Turing machine? This question (universality) has been recently analyzed by Terence Tao related to the problem of the regularity of the Euler and Navier-Stokes equations. In particular, Tao speculates on a connection between a potential blow-up of the Navier-Stokes equations, Turing completeness and fluid computation.

In the article under review the authors construct a steady incompressible fluid flow on a Riemannian 3-dimensional sphere that is Turing complete (i.e., it can simulate any Turing machine). This implies the existence of undecidable fluid particle paths, that is, there is no algorithm to ensure that a fluid particle will pass through a certain region of space in finite time. This inability to predict, which is different from that established by chaos theory, can be understood as a new manifestation of the turbulent behavior of fluids.

A steady fluid flow on a Riemannian 3-manifold (M, g) is described by the stationary Euler equations:

$$\begin{cases} \nabla_X X = -\nabla P\\ \operatorname{div} X = 0, \end{cases}$$

where X is the velocity field of the fluid (an autonomous vector field on M), P stands for the hydrodynamic pressure. Here $\nabla_X X$ denotes the covariant derivative of X along X.

To construct the aforementioned Turing complete Euler flow, the authors makes use of Beltrami fields, a particularly relevant class of stationary solutions of the Euler equations. Specifically, a divergence-free vector field X on (M, g) is Beltrami if it satisfies the equation

$\operatorname{curl} X = \lambda X$

for some constant $\lambda \neq 0$. We recall that the operator curlX is defined as the only vector field on M satisfying

$$i_{\text{curl}} X \mu_g = d (i_X g)$$

where μ_{g} is the Riemannian volume form.

The key aspect of Beltrami fields for the present work is their strong geometric content. Indeed, as first observed by Dennis Sullivan and substantially developed by John Etnyre and Robert Ghrist, any nonvanishing Beltrami field defines a contact structure on *M* and conversely, the Reeb field of a contact form is a Beltrami field for some adapted Riemannian metric. This Reeb-Beltrami correspondence turns out to be extremely useful to construct steady Euler flows that exhibit complex dynamics: one first constructs Reeb fields exhibiting the desired properties (exploiting the flexibility of the contact and symplectic worlds) and then the aforementioned correspondence yields a Beltrami field for some metric.

To construct a Turing complete Reeb flow, the authors make use of a deep connection between Turing machines and symbolic dynamics. A Turing machine is a mathematical computer manipulating a set of symbols on a tape following some specific rules. It receives, as input data, a sequence of zeros and ones and, after a number of steps, returns a result, also in the form of zeros and ones. More concretely: A Turing machine is defined as $T = \{Q, q_0, q_{halt}, \Sigma, \delta\}$, where Q is a finite set of states, including an initial state q_0 and a halting state q_{halt}, Σ is the alphabet, and $\delta : \{Q \times \Sigma\} \rightarrow \{Q \times \Sigma \times \{-1, 0, 1\}\}$ is the transition function. The input of a Turing machine is the current state $q \in Q$ and the current tape $t = \{t_n\}_{n \in \mathbb{Z}} \in \Sigma^{\mathbb{Z}}$. If the current state is q_{halt} , then halt the algorithm and return tas output. Otherwise compute $\delta\{q, t_0\} = \{q', t'_0, \varepsilon\}$, replace q with q', t_0 with t'_0 and t by the ε -shifted tape.

A dynamical system on M (e.g. a steady Euler ow) is Turing complete if it can simulate any Turing machine. This means that the halting of any Turing machine with a given input is equivalent to a certain bounded trajectory of the dynamics entering a certain open set of M. This can be understood as a mathematical fluid computer; it takes as input data a point in space, processes it (following the trajectory of the fluid through that point) and its outcome is the next region to which the fluid has moved.

Using the theory of generalized shifts developed by Moore in the early 1990s, the authors construct an area-preserving diffeomorphism of the disk $\varphi: D \rightarrow D$, that is Turing complete. More precisely, the restriction of φ to the square Cantor set is conjugate to the transition function of a universal Turing machine (using a canonical assignment between configurations of a Turing machine and points on the square Cantor set).

Then, a suspension technique from symplectic geometry (which in particular also employs Moser's path method) allows the authors to embed the diffeomorphism φ as the Poincaré map on a certain cross section of a Reeb field R defined on the 3-sphere. By construction, R is Turing complete as well and all the computations associated to the universal Turing machine take place on a compact subset of a solid torus $T \subset S^3$. Accordingly, the aforementioned Reeb-Beltrami correspondence implies the existence of a Riemannian metric g on S^3 for which R satisfies the equation $\operatorname{curl}_g R = R$, so it becomes a Beltrami field on (S^3, g) . Moreover, the metric g is the canonical one in the complement of the solid torus T. This completes the proof of the theorem.

"Matrix product states and projected entangled pair states: concepts, symmetries, theorems"

Authors: J. Ignacio Cirac, David Pérez-García (ICMAT-UCM), Norbert Schuch, and Frank Verstraete

Source: Reviews in Moderns Physics vol. 93, iss. 4

Date of publication: 17 December 2021



Review:

When talking about different *phases* in physics, the first thing that comes to mind is the division in solid, liquid and gas, where temperature is the varying parameter which connects them through phase transition points. At zero (or close to zero) temperature, where quantum mechanics is the physical law that governs the system, there are also different phases interconnected via phase transitions. Now what usually varies is some parameter or parameters in the model under study. The exotic and unexpected properties of some of these quantum phases, like superconductivity, super fluidity, fractional statistics, topological dependency, etc. have attracted the attention of physicists for many years.

Is there a way to classify all quantum phases of matter? Solving this question has been a major program for the mathematical physics community during the last decades. The family of Projected Entangled Pair States (PEPS), introduced by Cirac and Verstraete in 2004 and rooted in the seminal work "Finitely Correlated States" by Fannes, Nachtergaele and Werner in the early 90s, has been one of the key tools to address it.

PEPS have two key properties. On the one hand, they approximate well all low energy states of quantum many body systems and then, they are complex enough to cover all quantum phases of matter. On the other hand, all the global properties of a PEPS are encoded in a particular local tensor, which can be understood as the DNA of the system, from where all global, observable, properties, can be in principle obtained.

The problem of the classification of phases reduced then to understand how global properties are characterized locally in PEPS. This local vs global behavior is a problem that appears recurrently in many areas and problems in mathematics.

The main goal of the article "Matrix product states and projected entangled pair states: Concepts, symmetries, theorems" is to review the state of the art regarding this problem. Maybe non-surprisingly, since in the end physics is all about symmetries, they are precisely the symmetries of the local tensor which make the whole plethora of exotic global properties emerge.

Of course, the whole point is to understand the relevant mathematical objects behind those symmetries, which turn out to be in this case a pretty abstract generalization of the notion of group, called weak Hopf algebras. The elementary objects in the representation theory of weak Hopf algebras can be understood precisely as particles that can fuse together generating new particles, following a set of "fusion rules". It is precisely the behavior of those "particles" the one responsible for the global properties of the state.

The same techniques required to prove those results extend well beyond the problem of classifying quantum phases of matter. For instance, they also allow to study and classify Quantum Cellular Automata, to analyze the life-time of quantum memories, or even to design new machine learning methods with higher privacy guarantees.



Figure: A local tensor (right), represented graphically as a box with legs associated to the different indices in the tensor, defines a global many body quantum state by contracting a Tensor Network (left) in a lattice that encodes the interactions between the different constituents of the quantum system.

"Hypothesis Testing in Presence of Adversaries"

Authors: Jorge González-Ortega (ICMAT-UCM), David Ríos (ICMAT-CSIC), Fabrizio Ruggeri and Refik Soyer

Source: The American Statistician vol. 75, iss. 1

Date of publication: 2021

<u>Link</u>

Review:

Hypothesis testing is one of the fundamental problems in statistical inference. Though subject to debate, it has been thoroughly studied from a decision theoretical perspective, both from the frequentist and Bayesian points of view. In recent years, there has been an increasing interest in issues related with hypothesis testing problems in which hostile adversaries perturb the data observed by a decision maker as a way to confound her about the relevant hypothesis so as to attain some objectives. These cover applications like online fraud or spam detection and fooling classifiers in applied domains like national and homeland security, cybersecurity and automated driving systems and forms part of the emergent field of adversarial machine learning.

In this article, using concepts from Adversarial Risk Analysis (ARA), Jorge González-Ortega, David Ríos, Fabrizio Ruggeri and Refik Soyer provide an alternative novel approach to the Adversarial Hypothesis Testing (AHT) problem, formerly based typically on standard game-theoretic concepts. They consider an agent, called the defender (she), who needs to assess which of several hypotheses holds, based on observations from a source that might have been perturbed by another agent, which they designate attacker (he) and study the AHT problem from the defender's perspective. In doing this, the defender formulates a Bayesian decision making problem but has to forecast the attacker's decision; this is a non-standard forecasting problem as it entails strategic elements. They make such forecast by simulating from the attacker's perspective and preferences.

The article begins by introducing what they term the Adversarial Statistical Decision Theory problem, extending the standard Statistical Decision Theory formulation to consider an adversarial variation in which the attacker tries to modify the dataflow observed by the defender to confound her and, consequently, attain a profit. After that, they pose the AHT problem formally and provide a conceptual solution focusing on a binary point hypothesis testing, as well as illustrating it with a simple numerical example and presenting a game theoretic perspective for comparison purposes. Then, they describe in depth an application in relation with batch acceptance. This problem consists of deciding whether to accept a batch of items received over a period of time, some of which could be faulty, thus entailing potential security and/or performance problems. This type of issues arises in areas such as screening containers at international ports, filtering batches of electronic messages or admitting packages of perishable products or electronic components, among others.

Further applications may be found in the context of, for example, adversarial signal processing, such as in Electronic Warfare (EW) where pulse/signal environment is generally very complex with many different radars transmitting simultaneously. Time interval between two pulses emitted by a threat radar is defined as a Pulse Repetition Interval (PRI). PRI tracking is an important problem in naval EW applications as knowledge of the PRI is used to defend ships against radar-guided missiles. The signals received may be jammed by hostile radars and this results in missing pulses due to reduced sensitivity of the receiver.

"Automorphism group of the moduli space of parabolic bundles over a curve"

Authors: David Alfaya and Tomás L. Gómez (ICMAT-CSIC)

Source: Advances in Mathematics vol. 393

Date of publication: 24 December 2021

<u>Link</u>

Review:

Let X be a complex smooth projective surface (equivalently, a compact Riemann surface), and let D be a finite set of points of X. A parabolic bundle is a vector bundle E on X together with a weighted filtration of the fibre of E over each point x in D. By a weighted filtration we mean a filtration by subspaces such that each subspace has associated certain real number called weight. Parabolic bundles were introduced by Seshadri (1977), and they are related to representations of the fundamental group of the punctured Riemann surface with fixed holonomy around the points in D.

We associate to the pair (X,D) a moduli space of parabolic vector bundles of fixed rank r, and the present paper studies certain geometric aspects of this moduli space. We first prove a Torelli type theorem for this moduli space. This means that, if M and M' are the moduli spaces associated to (X, D) and (X', D'), and if M and M' are isomorphic, then there is an isomorphism between X and X' which sends D to D'. In other words, we can recover the curve X and the points D from the isomorphism class of the moduli space as an algebraic variety. This was known by del Baño, Balaji and Biswas (2001) only for rank r = 2, degree 1 and small parabolic weights, but here it is proved in general.

Then the authors calculate the automorphism group of the moduli space *M*. The case where there is no parabolic structure was settled by Kouvidakis and Pantev (1995). In the situation considered, the parabolic structure produces new maps (defined using Hecke transforms). These maps might have singularities, so instead of morphisms they define 3-rational maps (this means a map which fails to be defined on a subset of codimension at least 3). This is due to the fact that the Hecke transform might not preserve the condition of stability (which depends on the parabolic weights) and it is a phenomenon which also happens for other types of transformations of parabolic bundles. Motivated by this, the researchers also calculate the group of 3-birational transformations.

"Gravitating vortices with positive curvature"

Authors: Mario Garcia-Fernandez (ICMAT-UAM), Vamsi Pritham Pingali and Chengjian Yao

Source: Advances in Mathematics vol. 388

Date of publication: 17 September 2021

<u>Link</u>

Review:

A combination of ideas from cosmology and particle physics suggests the existence of symmetry-breaking phase transitions in the very early universe, as it expanded and cooled down. Like the transitions in condensed matter, <u>they may have led</u> to the <u>forma-</u> <u>tion of cosmic strings</u>, exceedingly narrow filaments of primordial material left over from the early moments of the universe. The basic mathematical structure of a cosmic string is <u>given by a spe-</u> <u>cial instance of Einstein's field equations</u>, known as the *self-dual* *Einstein-Maxwell-Higgs equations*, coupling gravity with an *electro-magnetic field* and a *Higgs field*. Solutions to these equations saturate a suitable energy bound (often called Bogomol'nyi bound) and typically have a *self-similar behaviour*, as solitons in the theory of parabolic partial differential equations. Geometrically, the strings are located at the zeros of the Higgs field (a complex scalar), and cut transversally a surface which is embedded in a space-like hypersurface in space-time.

A surprising relation between solutions of the self-dual Einstein-Maxwell-Higgs equations and algebraic geometry was found by L. Álvarez-Cónsul (ICMAT-CSIC), M. Garcia-Fernandez (ICMAT-UAM) and O. García-Prada (ICMAT-CSIC). The basic idea is that the Higgs field determines an effective divisor on a Riemann surface (that is, a distribution of delta sources with masses, concentrated at points), which must satisfy a balancing condition with origins in the Geometric Invariant Theory (GIT), as introduced by D. Mumford in the 1960s to construct quotients by group actions in algebraic geometry. This has led in recent years, jointly with V. Pingali (IISc, Bangalore), to the discovery of <u>new obstructions to the existence of cosmic string solutions</u> and also to a natural generalization of the theory for a more general system of PDE known as the *gravitating vortex equations*.

Building on these works, in this publication in Advances in Mathematics, M. Garcia-Fernandez (ICMAT-UAM), V. Pingali (IISc, Bangalore) and C. Yao (Shanghai Tech) give a complete solution to the existence problem for gravitating vortices with non-negative topological constant $c \ge 0$ in a compact surface. Their first main result builds on previous results by Yang and establishes the existence of solutions to the self-dual Einstein-Maxwell-Higgs equations, corresponding to c = 0, for all admissible volumes (Kähler classes). Their second main result completely solves the existence problem for $c \rightarrow 0$. Both results are proved by the continuity method and require that a GIT stability condition, for an effective divisor on the Riemann sphere, is satisfied. For the former, the continuity path starts from a given solution with *c*=0 and deforms the total volume of the solution. For the latter result the authors start from the established solution in any fixed admissible volume and deform the gravitational constant α towards 0. A salient feature of their argument is a new bound $S \ge c$ for the Gauss curvature of gravitating vortices, which is applied to construct a limiting solution along the path via Cheeger-Gromov theory.

"Global well-posedness for the 2D stable Muskat problem in $\mathrm{H}^{3/2^{\prime\prime}}$

Authors: Diego Córdoba (ICMAT-CSIC) and Omar Lazar

Source: Annales scientifiques de l'École normale supérieure

Date of publication: 2021

<u>Link</u>

Review:

The Muskat problem models the motion of an interface separating two incompressible fluids in a porous medium. Let's assume that both fluids are immiscible. The non-mixture condition allows one to consider the interface between these two fluids. Darcy's law, together with the conservation of mass and the incompressibility of the fluids is the so-called incompressible porous media system (IPM system).

For the Muskat problem the IPM system can be rewritten in terms of the dynamics of the interface in between both fluids by using standard potential theory and this leads to the evolution equation of the interface (Muskat equation). Recently, it has been proved that some solutions can pass from the stable to the unstable regime and return back to the stable regime before the solution breaks



down. This shift of stability phenomena illustrates the unpredictability of the solutions to the Muskat equation even starting in the stable regime. Moreover, there is numerical evidence of initial data whose slope is 50 that develops an infinite slope in finite time.

In this paper, the authors develop $\dot{H}^{3/2}$ critical theory under an arbitrary bounded slope assumption. The approach is completely new and is based on a reformulation of the usual Muskat equation. This new formulation allows one to take advantage of the oscillations which are crucial in this problem. There are many ways of measuring smoothness while trying to do a priori estimates in critical spaces. Contrarily to (almost) all previous works in the Muskat equation we shall never split the study into high/low frequencies or small/big increment in the finite difference operator. On the contrary, we shall consider the interaction between both and the Besov spaces techniques will be the main tool to achieve this. It is worth saying that the new formulation of the problem turns out to be crucial to prove the main theorems of this paper since it gives new features that are very difficult to see in the original formulation.

This article is a significant step in understanding the theory of global well-posedness of large solutions in the Lipschitz space. Indeed, the main result of this paper is the global well-posedness of strong solution in $\dot{H}^{5/2} \cap \dot{H}^{3/2}$ under a smallness assumption on the $\dot{H}^{3/2}$ norm of the initial data. It would not be possible to prove a global result for all data in the Lipschitz space since there has been shown that there are solutions with initial data having a (relatively) high slopes that become singular in finite time showing the instability of the Cauchy problem associated to initial data in critical spaces.

"Structure preserving reduced attitude control of gyroscopes"

Authors: Nidhish Raja, Leonardo J. Colombo (ICMAT), Ashutosh Simha

Source: Automatica vol. 125

Date of publication: March 2021

<u>Link</u>

Review:

Control system design for spinning axis-symmetric rigid bodies (henceforth called gyroscopes) plays an important role in mechanical systems such as gyroscopes, spinning satellites and spacecrafts, and underactuated multi-rotors. These systems are typically modeled as rigid bodies with constant spin about the body fixed axis of symmetry, and the spin rate is an order of magnitude higher than the angular velocity about the other axes. From a control design perspective, the main characteristic that distinguishes the dynamics of these systems from conventional rigid body systems is that, the gyroscopic torque contributes significantly to the overall system dynamics and consequently poses non-trivial challenges in control design.

In this paper, the authors have developed a geometric control law for reorienting the spin axis of a gyroscope which preserves the gyroscopic stability in the closed-loop dynamics. The control law thereby enables efficient maneuvering and also exploits the preserved inherent gyroscopic stability. They have shown via phase-portrait analysis that under high spin conditions, the spin axis rotates on an average about an axis perpendicular to the axis of applied torque. Based on this fact, a reduced attitude controller is developed such that the error dynamics preserves the gyroscopic stability structure of the original spinning rigid body dynamics. The proposed control law is a geometric proportional-derivative law, which is almost-globally exponentially stable and does not depend on moment of inertia parameters i.e. does not cancel gyroscopic terms. This control law is then modified to account for first order actuator dynamics, and is subsequently appended with an observer in order to avoid computation of angular acceleration, which is not directly obtained from sensors. The performance of the proposed structure preserving reduced attitude controller has been demonstrated via simulations and compared with a standard geometric controller. The controller has been also validated experimentally on a spinning tricopter.

"Entangleability of cones"

Authors: Guillaume Aubrun, Ludovico Lami, Carlos Palazuelos (ICMAT-UCM) and Martin Plávala

Source: Geometric and Functional Analysis vol. 31, pages 181–205

Date of publication: 15 May 2021

Link

Review:

The tensor product of cones appears naturally when one studies linear maps between cones (that is, positive operators). Given two cones C1 and C2, one can define two natural cones: the minimal one C1 \square C2 := Conv{x1 \bigotimes x2: x1 \in C1, x2 \in C2} and the maximal one C1 \square C2 := (C1* \square C2*)*, where here C* denotes the dual cone of C.

In this paper the authors study the following fundamental question: for which pairs of cones (C1, C2), do we have that C1¤C2 = C1℃C2? This question dates back to the work of Barker and Namioka-Phelps in the 1970s. The main result provides a simple characterization of those cones for which the equality above holds, which was conjectured by Barker 40 years ago.

In order to state this main result in precise terms, we need to introduce some notation: Given a d-dimensional real linear space V, we say that $C \subset V$ is a proper cone, if C is a closed convex cone such that C-C=V and C \cap [-C]={0}. Motivated by a physical interpretation of this problem, we say that C is classical if it is generated by a linearly independent set (or, equivalently, if it is linearly isomorphic to \mathbb{R}^{d}_{+}]. It is easy to see that if C1 or C2 is classical, then C1 \mathbb{Z} C2 = C1 \mathbf{O} C2, and it was conjectured by Barker that the converse implication should also be true. The main result of the paper proves that conjecture: given two proper cones C1 and C2, then C1 \mathbb{Z} C2 = C1 \mathbf{O} C2 if and only if one of the cones is classical.

"Uniform rectifiability and elliptic operators satisfying a Carleson measure condition"

Authors: Steve Hofmann, José María Martell (ICMAT-CSIC), Svitlana Mayboroda, Tatiana Toro and Zihui Zhao

Source: Geometric and Functional Analysis vol. 31

Date of publication: 8 May 2021

<u>Link</u>

Review:

This paper establishes the correspondence between the properties of the solutions of a class of PDEs and the geometry of sets in Euclidean space. The authors settle the question of whether (quantitative) absolute continuity of the elliptic measure with respect to the surface measure and uniform rectifiability of the boundary are equivalent, in an optimal class of divergence form elliptic operators satisfying a suitable Carleson measure condition in uniform domains with Ahlfors regular boundaries. The result can be viewed as a quantitative analogue of the Wiener criterion adapted to the singular L_a data case. The first step is to consider the case in which the desired Carleson measure condition on the coefficients holds with *sufficiently small constant*, using a novel application of techniques developed in geometric measure theory. Then, they establish the final result, that is, the "large constant case". The key elements are a powerful extrapolation argument, which provides a general pathway to self-improve scale-invariant small constant estimates, and a new mechanism to transfer quantitative absolute continuity of elliptic measure between a domain and its subdomains.

"Singular integrals in quantum euclidean spaces"

Authors: Adrián Manuel González-Pérez, Marius Junge and Javier Parcet (ICMAT-CSIC)

Source: Memoirs of the American Mathematical Society vol. 272 no. 1334

Date of publication: July 2021

Link

Review:

In the work reported here, the core of singular integral theory and pseudo-differential calculus are established on the model algebras for noncommutative geometry: quantum forms of tori and Euclidean spaces. The latter -also known as Moyal deformations in theoretical physics or CCR algebras in quantum probability- include the Heisenberg-Weyl algebra determined by the position and the momentum in quantum mechanics. These results on pseudo-differential operators go beyond the work of Connes, thanks to a new form of the Calderón-Zygmund theory in these algebras, which the authors develop in the same work and which crucially includes general kerrnels which are not of convolution type. This enables them to deduce L_{p} boundedness and p-Sobolev estimates for regular, exotic and for bidden symbols in the expected ranges. In L_2 they also generalize the <u>Bourdaud</u> and Calderón-Vaillancourt theorems for exotic and forbidden symbols. All the foregoing establishes the quantum forms of the most famous results of pseudo-differential operator theory. As an application of our methods, the researchers prove the L regularity of solutions to the first elliptic PDEs in von Neumann algebras.

Finally, it is worth pointing out that noncommutative Calderón-Zygmund theory has precedents in the work of the authors with interesting connections in geometric group theory and Lipschitz operator functions. However, unlike in the <u>previous results</u>, this is the first model that works in *purely noncommutative* algebras; that is, algebras that contain no copies of doubling metric spaces in the form of tensor products or crossed products. Recently, some of the authors <u>have developed an algebraic form of</u> <u>Calderón-Zygmund theory</u> that is valid in general von Neumann algebras equipped with a Markov process that satisfies strictly algebraic conditions.

Observers of quantum systems cannot agree to disagree

Authors: Patricia Contreras-Tejada (ICMAT-CSIC), Giannicola Scarpa, Aleksander M. Kubicki, Adam Brandenburger & Pierfrancesco La Mura

Source: Nature Communications vol. 12

Date of publication: 2 December 2021

Link

Review:

Is the world quantum? An active research line in quantum foundations is devoted to exploring what constraints can rule out the postquantum theories that are consistent with experimentally observed results. In this article, the authors explore this question in the context of epistemics, and ask whether agreement between observers can serve as a physical principle that must hold for any theory of the world. Aumann's seminal Agreement Theorem states that two observers (of classical systems) cannot agree to disagree.

Now, the researchers propose an extension of this theorem to no-signaling settings. In particular, they establish an Agreement Theorem for observers of quantum systems, while they construct examples of (postquantum) no-signaling boxes where observers can agree to disagree. The PR box is an extremal instance of this phenomenon. These results make it plausible that agreement between observers might be a physical principle, while they also establish links between the fields of epistemics and quantum information that seem worthy of further exploration.

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5. Books

During 2021, two book and 18 chapters of books were published with ICMAT researchers as coauthors; these are the references:

Books

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Book chapters

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6. Awards and distinctions

El ICMAT receives the CSIC Seal of Accreditation for Gender Equality



The CSIC has awarded its Seal of Accreditation for Gender Equality to the ICMAT, after it gained the "highest score from the panel," as stated in the official announcement of the decision, in which it was also stated that "it met the requirements set out in the National Plan for Equality" and highlighted "the commitment of both the management and the personnel of the institute in matters of equality." Likewise, the Institute for Environmental Diagnosis and Water Studies (IDAEA) and the Institute of Marine Sciences (ICM) were also distinguished with an honourable mention.

The ICMAT created its Gender Commission (now known as the Equality Commission) in 2016, as part of the Severo Ochoa Center of Excellence programme, awarded by the Ministry for Science and Innovation.

This distinction is also endowed with 5,000 euros for the development of initiatives promoting gender equality.

Antonio Córdoba receives the Royal Spanish Mathematical Society medal



Every year, the Royal Spanish Mathematical Society (RSME) awards its medals to "people outstanding for their relevant, exceptional and continual contribution to any area of mathematical endeavour." Among the three distinguished with an award in 2021 is Antonio Córdoba, ex-director (2016 - 2019) and now an associate member of ICMAT, as well as professor emeritus of mathematical analysis at the UAM. Together with him, Tomás Recio, a professor at the University of Cantabria, and Olga Gil Medrano, a professor at the University of Valencia, were also awarded a medal.

Córdoba has conducted his research in different areas, ranging from number theory to the study of harmonic analysis, partial differential equations and mathematical physics. His work has had a broad impact and has received international recognition, with publications in journals such as Annals of Mathematics, Inventiones Matematicae, Communications in Mathematical Physics, Proceedings of the National Academy of Sciences and Duke Mathematical Journal. He has been the recipient of distinguished prizes, among which is the Julio Rey Pastor Mathematics and Communication Sciences National Prize, which he was awarded in 2011.

David Pérez-García, Royal Academy of Sciences Ramón y Cajal Medal winner



On the third occasion of the distinction, the Royal Spanish Academy of Exact, Physical and Natural Sciences (RAC) has awarded the Ramón y Cajal Medal to David Pérez García, ICMAT researcher and professor at the Complutense University of Madrid (UCM). This distinction has been awarded since 2017 to researchers under 50 years of age for their scientific achievements; and this is the first time a mathematician has been bestowed with the medal.

Pérez García's research is focused on the applications of mathematics to quantum information theory. He leads the ICMAT Ignacio Cirac Laboratory on this topic and, also the Mathematics and Quantum Information research group at the UCM. Pérez García is the author of more than 90 papers published in high impact journals, Nature and PNAS among them. He is also the principal researcher of projects that amount to a total of more than five million euros, including an ERC Consolidator Grant that he obtained in 2015.

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7. Funding and research projects

Non-competitive public funding

Evolution of the total ICMAT funding since its creation, according to the four institutions of which it is composed (CSIC, UAM, UCM and UC3M), is shown in the following table:

2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
832k €	810k €	792k €	792k €	792k €	370k €	400k €	365k €	372k €	304k€	311k€

Competitive funding

National Plan

Code	Project	РІ	€	Start-final date
PID2020-116949GB-100	"Difusión no lineal: problemas locales y no locales"	Fernando Quirós	37 026 €	01/09/2021 - 31/08/2024
PID2020-113350GB-100	"Análisis armónico, combinatoria y aritmética"	Pablo Candela & Fernando Chamizo	30 492 €	01/09/2021 - 31/08/2024
PID2020-113523GB-100	"Análisis Matemático y Teoría de Información Cuántica"	Carlos Palazuelos & David Pérez-García	103 697 €	01/09/2021 - 31/08/2024
PID2020-118193GA-100	"Counting Conjectures (COCO)"	Carolina Vallejo	10 164 €	01/09/2021 - 31/08/2023
PID2020-114032GB-100	"Métodos Profinitos y Analíticos en Teoría de Grupos"	Andrei Jaikin	93 170 €	01/09/2021 - 31/08/2025
PID2020-116398GB-100	"Aplicaciones del Análisis Funcional en problemas de Geometría y Teoría de la Información"	Pedro Tradacete & José Ignacio Villanueva	32 912 €	01-09-2021 - 31/08/2025
PID2020-114703GB-100	"Dinámicas de fluidos incompresibles"	Ángel Castro & Diego Córdoba	72 600 €	01/09/2021 - 31/08/2024
EUR2020-112265	"El interfaz entre la geometria compleja kahler y no-kahler"	Mario García-Fernández	60 000 €	1/12/2020 – 30/11/2022
EIN2020-112197	"Análisis y Geometría de la Ecuación de Hamilton-Jacobi"	Manuel de León	10 000 €	1/11/2020 - 31/10/2022
EIN2020-112235	"Ayuda Europa Investigación para la preparación de una propuesta ERC SYNERGY GRANT"	Ana María Mancho	15 000 €	1/11/2020 - 31/10/2022
EIN2020-112392	"Hacia el motivo de los Espacios de Moduli de Fibrados de Higgs2"	Óscar García-Prada	10 000 €	1/11/2020 - 31/10/2022
PID2019-106715GB-C21	"Geometric structures in dynamical systems, mechanics and hydrodynamics"	David Martín & Daniel Peralta	78 287 €	01/06/2020 - 31/5/2023
PID2019-107914GB-100	"Fronteras del análisis armónico"	Javier Parcet & José Mª Martell	74 173 €	01/06/2020 - 31/05/2023
PID2019-108936GB-C21	"Simetrías e invariancia homotópica en aritmética y geometría: fundamento"	Francisco Presas & Daniel Macías	111 320 €	01/06/2020 - 31/05/2023



Code	Project	PI	€	Start-final date
PID2019-109339GB-C31	"Espacios de Moduli y Teoría de Gauge"	Oscar García-Prada	37 147 €	01/01/2020 - 31/12/2022
PID2019-109339GA-C32	"Non-Kähler geometry and mirror symmetry"	Mario García-Fernández	31 823 €	01/01/2020 - 31/12/2022
PID2019-103860GB-100	"Aspectos lineales y no lineales en ecuaciones en derivadas parciales. Dinamica asintótica y perturbaciones"	José María Arrieta & Aníbal Rodríguez	55 600 €	01/01/2020 - 31/12/2022
PID2019-105979GB-100	"Operadores y Geometría en Análisis Matemático"	Eva Gallardo	74 103 €	01/01/2020 - 31/12/2022
PID2019- 110712GB-100	"Ecuaciones con perturbaciones de potencias de Laplaciano"	Fernando Soria & Ana Primo	55 660 €	01/06/2020 - 31/05/2023
CEX2019-000904-S	"Apoyo a Centros de Excelencia Severo Ochoa"	Diego Córdoba	4 000 000 €	01/01/2020 - 31/12/2023
RED2018-102810-T	"Red Temática de Geometría y Física"	Oscar García-Prada	16 000 €	1/1/2020 - 31/07/2022
EIN2019-103354	"The interface between Kähler and non-Kähler geometry"	Mario García-Fernández	10 000 €	1/6/2019 - 31/05/2022
EIN2019-103037	"New applications o geometric integration in engineering"	David Martín	15 500 €	01-06-2019 - 31/12/2021
EUR2019-103821	"Estructuras Topológicas en EDPs"	Daniel Peralta	75 000€	1/10/2019 - 31/12/2021
PGC2018-101179-B-I00	"Propiedades de grupos de automorfismos y estructuras relacionadas"	Javier Aramayona	13 068 €	01/01/2019 - 31/12/2021
PGC2018-095392-B-I00	"Geometría algebraica y aritmética"	Orlando Villamayor	68 365 €	1/1/2019 - 31/12/2021
MTM2017-85934-C3-1-P	"Análisis y geometría con aplicaciones a problemas inversos"	Keith Rogers	13 915 €	01/01/2018 - 31/12/2021
MTM2017-85934-C3-2-P	"Cálculo de variaciones y geometría con aplicaciones a mecánica de medios continuos y problemas inversos"	Luis Guijarro & Daniel Faraco	69 454 €	01/01/2018 - 31/12/2021
MTM2017-89423-P	"Singularities in free surfaceflows"	Marco Antonio Fontelos	28 677 €	01/01/18 - 31/12/2020
MTM2017-89976-P	"Formación de singularidades en fluidos incompresibles"	Diego Córdoba	51 425 €	01/01/18 - 31/12/2020
MTM2017-86875-C3-1-R	"Avances en gestión de riesgos para la seguridad"	David Ríos	32 186 €	01/01/18 - 31/12/2020
MTM2017-82690-P	"Invariantes asintóticos de grupos"	Andrei Jaikin	36 300 €	01/01/2018 - 31/09/2021
MTM2017-88385-P	"Métodos matemáticos en información cuántica"	Ignacio Villanueva & Carlos Palazuelos	35 332 €	01/01/2018 - 31/09/2021
MTM2017-82105-P	"Estructuras Algebraicas, Analíticas y o-Minimales STRNAO"	José Francisco Fernando	51 425 €	01/01/2018 - 30/06/2022
MTM2017-87596-P	"Problemas no lineales de difusión"	Fernando Quirós	40 535 €	01/01/2018-30/09/2021

CSIC (I-Link and I-Coop) Calls

CSIC (I-Link, I-Coop and Extraordinary Grants) Calls

Code	Project	PR	€	Start-final date
CSIC-I-LINK. LINKA20079	"The interplay between geometry, mechanics and control in multi-agent systems"	David Martín	24 000 €	01/01/2019 -31/12/2021
CSIC-I-COOP COOPA20398	"Existencia global de soluciones para la ecuación de IPM" Ángel Castro 24 000€		01/01/2020 - 31/12/2021	
20205CEX001	"Ayudas Extraordinarias Menciones Excelencia Severo Ochoa"	Diego Córdoba	142 080 €	01/01/2020 – 31/12/2021

Regional programs

Code	Project	PI	€	Start-final date
SI1/PJI/2019-00514	"Desigualdades de martingalas no conmutativas"	José Manuel Conde	20 700 €	01/01/2020 - 31/12/2022
S2018/TCS-4342	"Quantum Information Technologies Madrid+ (QUITEMAD+-CM)"	ntum Information Technologies Madrid+ (QUITEMAD+-CM)" David Martín		01/01/2019 - 31/12/2022
IND2018/TIC-9901.	"Grant from the Madrid Government for Industrial Doctorate. Researcher: Bruno Flores"	David Ríos	64 000 €	26/02/2019 - 25/02/2022

International Funding

Internationally, the European Union is the main source of funding for the ICMAT.

European Research Council Grants

Acronym	Reference	Project	PR	EU Funding	Start-final date
GEOFLUIDS	ERC- Starting Grant 633152	"Geometric problems in PDEs with applications to fluid mechanics"	Alberto Enciso	1 256 375 €	01/03/2015- 28/02/2021
GAPS	ERC- Consolidator Grant 648913	"Spectral gaps in interacting quantum systems"	David Pérez-García	1 462 750 €	01/09/2015 – 28/02/2022
FLUSPEC	ERC-Consolidator Grant 862342	"Analysis of gemotry-driven phenomena in fluid mechanics, PDEs and spectral theory"	Alberto Enciso	1 825 163 €	01/03/2021- 28/02/2026
NONFLU	ERC- Advanced Grant 788250	"Non-local dynamics in incompressible fluids"	Diego Córdoba	1 779 369 €	01/09/2018– 31/08/2023
QUAMAP	ERC- Advanced Grant 834728	"Quasiconformal Methods in Analysis and Applications"	Kari Astala. ICMAT members: Daniel Faraco and Keith Rogers	Total: 2 280 350 € ICMAT: 771 850 €	01/09/2019- 31/08/2024



Marie-Sklodowska Curie actions

RESTRICTIONAPP	Marie Curie - Individual Fellowship 841228	"A multilinear approach to the restriction problem with applications to geometric measure theory, the Schrödinger equation and inverse problems"	Javier Ramos and Keith Rogers	172 932,48 €	01/08/19 – 02/10/2021
techFRONT	Marie Curie - Individual Fellowship 839749	"Novel techniques for quantitative behaviour of convection-diffusion equations"	Matteo Bonforte	172 932 €	01/09/2020 - 31/08/2022
ROBOTTOPES	Marie Curie - Individual Fellowship 846722	"The momentum polytopes of nonholonomic systems"	Amna Shaddad and Manuel de León	160 932 €	16/09/2020 - 15/09/2022
RRMAP	Marie Curie - Individual Fellowship 897784	"Riemann-Roch and motives for arithmetic problems"	Alberto Navarro and José Ignacio Burgos	172 932,48 €	01/01/2021 - 31/12/2022
TraX	Marie Curie-IRSE 734557	"Stability and Transitions in Physical Processes"	Florentino Borondo	Total: 526 500 € ICMAT: 63 000 €	01/03/2017 - 31/10/2022
GHAIA	Marie Curie-RISE 777822	"Geometric and Harmonic Analysis withInterdisciplinary Applications"	Matteo Bonforte	Total:1 782 000 €; ICMAT budget 765 000 €	001/10/2017 - 30/04/2022

H2020 Industrial Leadership Pillar

Acronym	Reference	Project	PI	EU Funding	Start-final date
IMPRESSIVE	821922	"Integrated Marine Pollution Risk assessment and Emergency management Support Service In ports and coastal enVironmEnts"	Ana María Mancho	176 315 €	01/12/2018 – 31/05/2021

H2020 Societal Challenges Pillar

Acronym	Reference	Project	PI	EU Funding	Start-final date
Trustonomy	815003	"Building Acceptance and Trust in Autonomous Mobility"	David Ríos	Total: 3 920 000 € ICMAT: 206 500 €	01/05/2019 - 30/04/2022

Other projects

US Air Force Office of Scientific Research (AFORS)

Acronym	Project	PR	Funding	Start-final date
RC2APD	"Robust Command and Control under Adversarially Perturbed Data"	David Ríos	58 699,52 \$	22/09/2021 - 21/09/2024

Private funding

Title	Reference	Project	PI	Funding	Start-final date
Axa Permanent Chair	01AXACT01	"Análisis de Riesgo Adversario"	David Ríos	1 100 000 €	01/09/2014 - 31/12/2023
Fundación BBVA – Becas Leonardo	-	"Garantías de Seguridad con Controles Basados en Datos para Sistemas Cooperativos"	Leonardo Colombo	39 987 €	30/10/2020 - 30/04/2022
Fundación BBVA	AMALFY	"Adversarial Machine Learning: Methods, Computations and Applications to Malware, Fake News and Autonomous Vehicles"	David Martin	100 000 €	30/04/2020 - 30/04/2022
Fundación La Caixa. Junior Leather	-	"Decentralized Strategies for Cooperative Robotic Swarms"	Leonardo Colombo	305 000 €	01/05/2019 - 31/08/2022
Fundación La Caixa. Becas de doctorado INPhINIT	-	"Dynamical and Numerical Aspects of Multi- agent Control Systems with Applications to Robotics"	Jacob Goodman	122 592 €	28/01/2020 - 27/01/2023
Fundación La Caixa. Becas de doctorado INPhINIT	-	"The smooth topology of symplectic 4-manifolds with a fixed contact boundary"	Didac Violan y Francisco Presas	122 592 €	01/10/2020-30/09- 2022
Fundación La Caixa. Becas de doctorado INPhINIT	-	"Machine learning for partial differential equations"	Laia Domingo y Florentino Borondo	122 592 €	15/10/2020- 14/10/2022
XEERPA MARKETING SOLUTIONS, SL	-	"Recomendador de Contenidos Basado en el Perfil Digital de un Usuario/ Content Recommender Based on a User's Digital Profile"	David Ríos	90 750 €	29/09/2019- 28/02/2022
EVERIS Spain SLU	-	"Utilización de técnicas de análisis de riesgos adversarios para desarrollar una aproximación a problemas competitivos de negocio con foco en la situación; estudio de movimientos estratégicos del sector bancario español"	Roi Naveiro	60 000 €	22/03/2021- 21/10/2021
DENEXUS TECH S.L.	-	"Modelización del riesgo unitario y acumulación de riesgo derivado de la ciberseguridad para el desarrollo de la versión 4 del producto DeRISK"	David Ríos	45 232 €	24/10/2021- 24/02/2022



8. Severo Ochoa Programme

In December, 2020, and for the third consecutive time, the ICMAT was awarded the Severo Ochoa seal of excellence by the Spanish Ministry of Science and Innovation.

The purpose of the "Severo Ochoa Centres of Excellence and the María de Maeztu Units of Excellence" awards is to provide funding and accreditation to research centres and units in any field of science that demonstrate impact and scientific leadership at an international level, and collaborate actively with their social environment and business sectors.

This accreditation is endowed with four million euros for the development of a programme, with the objective of strengthening institutional capacity over a four-year period, and includes 14 predoctoral contracts. This enables the creation and implementation different scientific programmes, which will make a huge contribution towards consolidating ICMAT's position as a leading international centres in mathematical research.

As on previous occasions, a big part of the funding this year is devoted to hiring personnel, including management experts, and pre- and post-doc researchers whose role is central to the development of ICMAT's programme of excellence. Likewise, this funding has also covered temporary transfers of contracted research personnel, as well as seven collaboration grants for master students, who have had their fees covered and received a monthly stipend. Funding has also been provided for students in the final year of their degree to attend the JAE School and undertake research stays with members of the ICMAT.

In 2021, the ICMAT launched a third programme of Laboratories and Distinguished Professors that will last until 2023, with funds provided by the Severo Ochoa project. The chairs of the Labs are: Ian Agol (University of California, Berkeley, USA); Ngô Bảo Châu (University of Chicago, USA); Ignacio Cirac (Max Planck Institute of Quantum Optics, Germany); Charles Fefferman (Princeton University, USA) and Nigel Hitchin (University of Oxford, UK). The Distinguished Professors are: Kari Astala (University of Helsinki); Anthony Bloch (University of Michigan); Filippo Bracci (Università di Roma); Anthony Carbery (University of Edinburgh); Juncheng Wei (University of British Columbia).

Examples of activities funded by the Severo Ochoa during 2021 are the visit of the Distinguished Professor K. Astala, the Groups in Madrid workshop, the costs of different ICMAT seminars and colloquia, and the disthinguished lecture of C. Fefferman. In addition, funding was provided for the ICMAT's visitors scheme, which in 2021 enabled three researchers to carry out stays at the institute. Costs arising from outreach and communication activities conducted at the centre have also been covered, as well as those stemming of the Institute's gender plan, consumables and computer equipment, training costs of centre members, and representation costs.

Since October, 2017, the ICMAT has formed part of an alliance between the Severo Ochoa centres and the María de Maeztu Units, known as SOMMa. SOMMa gathers over 50 top Spanish research institutions with over 8500 researchers, was launched officially on October the 18th, 2017, with the support of then Secretary of State of Research of the Ministry of Economy, Carmen Vela, as an initiative to visibilize the Spanish science with the Severo Ochoa and María de Maeztu mentions of excellence of the Spanish State Plan for R+D+I.

On 26 May 2021, the Alliance conducted the II SOMMa Gender Equality Meeting (hold online), organized by the ICMAT.



EXCELENCIA SEVERO OCHOA



9. Scientific activities

The following activities have been organized in ICMAT in 2021: Workhops, schools and conferences

• XXII Winter Meeting on Geometry, Mechanics and Control (Zoom meeting)

18-19 February 2021

Web

- Multisymplectic models of General Relativity and Gravitation 14 June 2021
- Opening of the Hitchin-Ngô ICMAT Laboratory (Madrid) via Zoom

1 June 2021

Web

• Escuela JAE de Matemáticas 2021

21 June – 9 July 2021

<u>Web</u>





• Symposium: New Developments in Momentum Polytope Theory

26 – 30 July 2021

<u>Web</u>

• Summer School: New Developments in Momentum Polytope Theory

2 – 5 August 2021

Web

• XXIX International Fall Workshop in Geometry and Physics

7 - 10 September 2021

Web

• ICMAT postdoc presentation day

22 October and 5 November 2021

• Interdisciplinary symposium: Prediction, Death and Memory: Numbers | Spaces | Texts

2 November 2021

<u>Web</u>

• Groups in Madrid 2021

25 – 26 November 2021

<u>Web</u>



Courses, conferences and working groups

• IAN AGOL LABORATORY: Study Seminar on Sylvester rank functions and L2-Betti numbers

<u>Web</u>

 Mathematical Modelling and Simulation in Geophysical Flows: Computational issues

<u>Web</u>

• Mathematical Modelling and Simulation in Geophysical Flows: Computational tools

<u>Web</u>

• Mathematical Modelling and Simulation in Geophysical Flows: Mathematical concepts

<u>Web</u>

Study Group in Iwasawa Theory

<u>Web</u>

• BEWATS - Evento final del proyecto

28 May 2021

<u>Web</u>

Constrained discrete optimal control on Lie groups

19 – 23 April 2021

<u>Web</u>

• Jornada de primavera en EDP

9 April 2021 <u>Web</u>



Distinguished Lectures

The ICMAT launched in 2021 this new activity, a series of talks given by leading figures of international standing in mathematics. The opening lecture was delivered by Charles Fefferman, a professor at Princeton University, a Fields Medal winner and director of one of the ICMAT Laboratories.

• Talk 1: "Interpolation of data by smooth functions", talk 2:

"Mathematical problems on graphene"

15 October 2021

<u>Web</u>



Colloquia

The previous two colloquia, held together with UAM and UCM universities (Colloquium UAM-ICMAT; Colloquium ICMAT-UCM), have merged in just one joint colloquium in 2021: Joint Mathematics Colloquium (ICMAT-UAM-UC3M-UCM). Besides, the Junior seminar has been changed to a joint colloquium also: Joint Mathematics Junior Colloquium (ICMAT-UAM-UC3M-UC3M-UCM).

Joint Mathematics Colloquium (ICMAT-UAM-UC3M-UCM)

Coordinators: José Ignacio Burgos Gil (ICMAT-CSIC), José Manuel Conde Alonso (ICMAT-UAM), Fernando Lledó Macau (ICMAT-UC3M) and Piergiulio Tempesta (ICMAT-UCM)

"Bayesian networks and temporal data"

Concha Bielza (Department of Artificial Intelligence Technical University of Madrid)

1 October 2021

<u>Web</u>



 "From Euler equations to Turing machines via contact geometry"

Eva Miranda Galcerán (Universitat Politècnica de Catalunya) 30 November 2021

Joint Mathematics Junior Colloquium (ICMAT-UAM-UC3M-UCM)

Coordinators: Manuel Lainz (ICMAT-CSIC) and Adrián Linares (UAM)

 "Una introducción a la mecánica noholónoma" Alexandre Anahory Simões (ICMAT) 7 October 2021

Web

"Una perspectiva global del concepto de Grado Topológico"

Juan Carlos Sampedro Pascual, UCM

7 October 2021

<u>Web</u>

 "¿Puede un matemático entender la termodinámica elemental?"

Manuel Lainz (ICMAT)

25 November 2021

<u>Web</u>

Seminars

Seminars are held every week at the ICMAT on different areas of research:

- Analysis and applications seminar. Coordinator: José Conde (ICMAT - UAM)
- Analysis and PDE's seminar. Coordinators: Ángel Castro (ICMAT-CSIC), Francisco Gancedo (US-IMUS), Rafael Granero (UC) and Fernando Quirós (ICMAT-UAM)
- Applied Mathematics. Coordinators: Florentino Borondo (IC-MAT-UAM), Makrina Agaoglou (ICMAT-CSIC) and Guillermo García Sánchez (ICMAT-CSIC)
- Communtative Algebra-Algebraic and Aritmetic Geometry seminar UAM-ICMAT. Coordinator: Ana Bravo (ICMAT-UAM)
- DataLab Seminar. Coordinator: Roi Naveiro (ICMAT-CSIC)
- Geometry seminar. Coordinators: Benjamin Bode (ICMAT-CSIC), Mario García Fernández (ICMAT-UAM), Oscar García-Prada (ICMAT-CSIC), Ángel Gonzalez Prieto (ICMAT-UCM) and Daniel Peralta (ICMAT-CSIC)
- Geometric mechanics and control seminar. Coordinators: Manuel de León (ICMAT-CSIC), Juan Carlos Marrero (IMAULL), David Martín (ICMAT-CSIC)
- Group theory seminar. Coordinators: Leo Margolis (ICMAT-CSIC) and Dominik Francoeur (ICMAT-CSIC)
- Machine Learning seminar. Coordinators: Matteo Bonforte (ICMAT-UAM), Davide Barbieri (ICMAT-UAM) and Mar González (ICMAT-UAM)
- Number theory seminar. Coordinators: Enrique González Jiménez (UAM), Daniel Macías (ICMAT-UAM) and Pablo Candela (ICMAT-UAM)
- PDEs and fluid mechanics seminar. Coordinators: Ángel Castro (ICMAT-CSIC) and Diego Córdoba (ICMAT-CSIC)
- Q-Math seminar. Coordinator: Juan Manuel Pérez Pardo (ICMAT-UC3M)

<u>Web</u>

10. Theses

13 researchers completed their PhD theses at the ICMAT in 2021.

The titles, authors and supervisors of which are listed below:

- <u>A thesis submitted in fulfillment of the requirements for the</u> <u>degree of Doctor in Mathematics</u>, Alejando Gárriz Advisor: Fernando Quirós (ICMAT-UAM) Date: January 2021
- <u>Bell violations in quantum information: non-signalling, communication and multipartite scenarios</u>, Amr Rey
 Advisor: Carlos Palazuelos (ICMAT-UCM) e Ignacio Villanueva (ICMAT-UCM)
 Date: January 27, 2021
- <u>Sylvester rank functions, epic division rings, and the strong</u> <u>atiyah conjecture for loally indicable groups</u>, Diego López Advisor: Andrei Jaikin (ICMAT-UAM) Date: March 4, 2021



 <u>Amenability and coarse geometry of (inverse) semigroups</u> and c*-algebras, Diego Martínez

Advisor: Fernando Lledó (ICMAT-UC3M) Date: March 5, 2021

<u>On Dehn's decision problems in generalized Thompson's groups</u>, Julio Aroca
 Advisor: Javier Aramayona (ICMAT-CSIC)
 Date: March 26, 2021



 <u>The homotopy type of the contactomorphism group of a con-</u> <u>tact 3-manifold</u>, Eduardo Fernández Advisor: Francisco Presas (ICMAT-CSIC)
 Date: May 2021 • Resource characterisation of quantum entanglement and nonlocality in multipartite settings, Patricia Contreras-Tejada Advisors: Carlos Palazuelos (ICMAT-UCM) and Julio de Vicente (UC3M)

Date: July 2021

 Instabilities in fluid mechanics and convex integration, Francisco José Mengual Advisors: Ángel Castro (ICMAT-CSCI) and Daniel Faraco (ICMAT-UAM) Date: July 16, 2021

 Local Banach space theory and resource quantification in Quantum Information Processing, Aleksander Marcin Advisors: Carlos Palazuelos Cabezón (ICMAT-UCM) and David Pérez García (ICMAT-UCM)

- <u>Contributions to Large Scale Bayesian Inference and Adversarial Machine Learning</u>, Víctor Gallego Advisors: David Ríos (ICMAT-CSIC) David Gómez-Ullate (Universidad de Cádiz) Date: November 23, 2021
- <u>Geometric and Numerical Analysis of Nonholonomic Sys-</u> <u>tems</u>, Alexandre Anahory Advisors: David Martín (ICMAT-CSIC) and Juan Carlos Marrero (Universidad de La Laguna)

Date: November 26, 2021

Date: September 9, 2021



• <u>A dissertation submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Mathematical Engineering</u>, Aitor Balmaseda Advisors: Alberto Ibort (ICMAT-UC3M) and Juan Manuel Pérez (ICMAT-UC3M)

Date: November 26, 2021

 <u>Contributions to Approximate Bayesian Inference for Machine Learning</u>, Simón Rodríguez
 Advisors: Daniel Hernández (UAM) and David Gómez-Ullate (Universidad de Cádiz)

Date: December 21, 2021



11. Transfer activities

AXA-ICMAT Permanent Chair in Adversarial Risk Analysis

The AXA Chair in Adversarial Risk Analysis, funded by the AXA Foundation and directed by David Ríos, continued its activity throughout the year.

Ríos studies problems in which an individual or an organization may tackle threats presenting intelligent or adaptive behaviours. Specifically, he deals with problems such as the protection of critical infrastructures against terrorist attacks; the preparation of bids in an auction against other potential buyers, and the protection of computer systems against cyberattacks.

Unlike the standard risk analysis, adversarial risk analysis takes into account the intention of attackers, their objectives and their capacity to modify their strategy for achieving them.

International consortiums

In 2021, the ICMAT participated in two international consortiums:

 Integrated Marine Pollution Risk Assessment and Emergency Management Support Service In ports and coastal enVironmEnts (IMPRESSIVE)

Duration: 01/12/2018 - 31/05/2021

Participant: Ana María Mancho (ICMAT)

The aim of the IMPRESSIVE project is to develop a global platform for the real-time management of accidental marine pollution in and around ports of the European Union. The monitoring and advanced modelling of these areas is of great importance, since the traffic and refuelling of vessels involves a high risk of contamination due to spillage and effluents. Mathematics is vital for modelling the movement of ocean currents and the prediction on the effect of pollutants should they reach the coast.

The project is devising a protocol for action, which will be tested and validated in the Puerto de la Luz (Gran Canaria), the Port of Taranto (Italy) and the Port of Rafina (Greece).

<u>Web</u>

mage: ICMAT



IMPRESSIVE meeting at ICMAT.

 Building Acceptance and Trust in Autonomous Mobility (TRUSTONOMY)

Duration: 01/05/2019 - 30/04/2022

Participant: David Ríos (ICMAT)

In addition to the scientific and technological challenges arising from self-driving vehicles in complex and unpredictable surroundings, scientists also have to tackle other issues, such as analyzing the risks involved in these types of vehicles, designing communication between machine and human being, studying the impact on the economy and on certain sectors of industry. All of these questions are dealt with in the Trustonomy project.

As its title indicates, the main aim of the project is to create acceptance and trust in autonomous mobility. David Ríos is in charge of producing risk analysis models capable of responding to and predicting the specific hazards arising from this emerging form of travel and mobility. This scheme has received 3.9 million euros from the European Union H2020 programme.

<u>Web</u>

Quantum computing

The Mathematics and Quantum Information group, led by David Pérez-García (ICMAT-UCM), is one of the participants in the CSIC Quantum Technologies Platform. One of the advantages enjoyed by its members is that they are able to use IBM superconducting quantum computers (according to terms in the contract signed between the CSIC and IBM).

DataLab

The ICMAT DataLab group, headed by David Ríos, participates in the AIHub, the platform that designs the strategic plan of CSIC activities in the field of Artificial Intelligence (AI).

Moreover, in 2021 the group of David Ríos organized the following transfer projects:

- Contract: Xeerpa Marketing Solutions, S.L. "Recomendador de contenidos basado en el perfil digital de un usuario". 75 000 € 01/02/2020 - 31/01/2022.
- Grants for scientific research groups, Fundación BBVA: "AMALFI: Adversarial Machine Learning: Methods, Computations and Applications to Malware, Fake News and Autonomous Vehicles". 100 000 €, 30/04/2020 - 30/04/2022.

The following activities were organised as well:

Utilización de técnicas de análisis de riesgos adversarios para desarrollar una aproximación a problemas competitivos de negocio con foco en la situación; estudio de movimientos estratégicos del sector bancario español. **EVERIS Spain SLU**. 60 000 €. (March 22th, 2021 to October 21st, 2021). PI: Roi Naveiro Flores.

Modelización del riesgo unitario y acumulación de riesgo derivado de la ciberseguridad para el desarrollo de la versión 4 del producto DeRISK. DENEXUS TECH S.L. (24/10/2021-24/02/2022). 45 232,22 € (37282 € +IVA)PI: David Ríos.

12.Communication and outreach activities

Throughout 2021, the ICMAT continued its intense outreach and communication activity through the Culture Mathematical Union Office. Regular organization of activities continued with the publication of press releases, the ICMAT Newsletter, the 'Café y Teoremas' section in El País, and events, such as the Researchers Night, the Science Week or Matemáticas en la Residencia. A full list of the activities is as follows:

ICMAT Newsletter

The ICMAT publishes a news bulletin which reports on what happens in a centre of mathematical excellence. This newsletter presents subjects of interest regarding current mathematical research, as well as the scientific activities of the centre and personal profiles of notable figures in the scientific community. The authors of these articles are researchers from the Institute itself or other mathematicians who collaborate with the ICMAT, as well as a team of professional journalists in the field of mathematical communication and outreach.

Two issues of the ICMAT newsletter were published in 2021:

Newsletter #21





EDITORIAL

The ICMAT recognized for the third time for excellence



Betmake resolution of grants for the Severa Ochaa Center of latence districtions the ICMAI and mate other Spannsh research resolution of the ICMAI and material technologies and it is the therity are grant the heatstanding tracking and the second sound it is the result of the nationality in the recognition and it is the resolution of the nationality of the ICMAI and resolution of the national sound sound sound by the ICMAI a report of the nationality of the ICMAI and respectively those awarded by the IcMAI and respectively the sound sound by the ICMAI and ICMAI and ICMAI and the ICMAI and ICMAI and ICMAI and the ICMAI

It as one of the leading multimemoical research centers in Europe. The two previews Serven Ochea projects made a produced impact on the scientific life of the inditute, strengthening its internal structure and consolidating its different scientific programmes, which together have successfully helped to generate and attract mathematical table to the center. Including Lanco Cince (Max Planck Itsitume of Quantum Optics, Germany, Simon Donaldon dy and Physics, USA), Nigel Historin, Finland I, Ianaco Cince (Max Planck Itsitume of Quantum Optics, Germany, Simon Donaldon et y and Physics, USA), Nigel Historin (Dodor Ulmerinity, USA). In addition, Throughout this time the (MAN has pursued an in-tense scientific actively that has earned it a much grater visibi-ris on the international tabage; bitwene 2015 and 2016; the center has welcomed approximately 750 visitors, hosted more than 700 workhops and conferences and nine thematic programmes.

Notation and Concerned and nine memory programmers. Furthermore, funding through the Severo Ochao projects has comented coherion between the different institutes with rep-resentation at the ICMAT, particularly thanks on the grants for PhD programmes and joint seminars. This has also strength-ered the leadership of the institute in the field of mathematics at both a regional and a national level.

We now segerly enhance on this new phase with the determination and only to mantain but also to improve on the work undertaken in provious years. To this end, we have a our disposal an annual fund-ing of one million curues over the next four years, and are endowmered in 14 producted contracts as well as the opton to participate in post- and pre-doctoral programmes offered by La Caixa Foundation. pot- and pre-dectoral programmes defined by La Casia Foundation. Although 2020 has been an exceptional yara during which activity at the center has been drastically reduced due to health mesona, J an convinced that we can make the most of the new Severo Ochea programmes to enable us to get back up to speed with activity here the Institute. We will be running predoctral programmes Such as the master grants, the centracts associated with Severo Ochea and these We will be running predoctral programmes. Make Schooli post-dectoral programmes livel the full saids and the Al& Schooli post-dectoral programmes livel the full saids and the Al& Schooli post-dectoral programmes livel the full saids and the approgrammed. Future is the institute of the full saids and the such services control control saids of the programmes. We have a set of the service as the services of the services, were have and school pro-grammes and thematic and visitor programmes.

weise, the Severo Ochoa project also boltsters knowledge tra and of course the proactive popularization policy conducte invious years, the aim of which is to raise the profile of mathem in is society and to increase the number of students and won gaged in mathematics.

Diego Córdoba is the Scientific Director of the Severo Ochoa project at the ICMAT.

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Newsletter #22





EDITORIAL

Consequences that exceed the initial intention



Notice Encode is codirector after ECMAI Scientific Cormities. One of my forwardies starting is about the fictilitous village of Agloes in New York State (USA), in the 1930s, the test of the Status of a place bearing this name (an anagram formed from their initials) on the road map they were making in order to serve as a copyright trap to catch plagharists. In later years, when other maps also showed a ling called Agloes back (calced at a diversion anage size showed a ling called Agloes back costed at a diversion for copyright trap to catch plagharists. In later years, when other maps also showed and had no hestitotion is using others for copyright traps to calce plagharists. The consequences for copyright traps because of their dismay at to finding the village on the road map, people had built avillage themselves at the eract location of Agloe. Its reasing of one, the consequences of which may tar exceed the initial internitien.

A much more recent and well-known example is the car A much more recent and well-known example is the case of the cordi-19 pandemic and its impact on our lines, our jobs and our research work. The theoretical nature of mathematical research has enabled us to pursue our endeavours with fewer delays and difficulties than in other fields of science that require a groate degree of experimentation. However, the way in which we con duct work has also changed drastically in this period of time. The discipline of mathematics often involves discussions, Dakabbaar discipline of mathematics often imbles discussions, blackbard work and travel, but during the last twe years there has been far less travel, less use of chalk and less face-to-face interac-tion. Of course, this is only the tip of the iceberg. The teiphant in the room consists of mental health problems, mainly concorn-ing anxiety and depression, which constitute a well-document-ed occupational hazard in the work of research that has only grown worke with the increase in uncertainty and isolation as a



Press releases

The ICMAT regularly sends press releases to a broad range of journalists specializing in science and education, with the aim of keeping the general public informed about the activities of the Institute. In 2021, 11 press releases were prepared and issued, covering a wide variety of topics: from reports on new scientific results to information about events, the award of grants and prizes, etc. All these press releases are available on the ICMAT website.

'Café y Teoremas', *El País*



result of the pandemic and the feeling of insecurity caused by its recurring emergence. It is important to point out that these circumstances have particularly affected young people, whether are not they happen to be mathematicians; a collective that has requently been criticized in the media for flagrandly irrespon-sible social behaviour; even though the overwhelming majority have conducted themselves in an irreproachable way in highly adverse situations.

adverse situations. Since the beginning of the pandemic, the mathematical com-munity has soupht ways of mitigating the difficulties that have arism. Many of us have used digital lablesr rather than chalk, a change that has lent an almost epistolary nature to our ci-laborations, while our discussions have mainly been carried out using Zoom, Teams, Skype and Conecta. This has entailed the creation of new physical and menation spaces for working visivide link and for face-to-face interaction without going to the office or travelling by air, well as adapting timetables and work habits to a series of compix and uncertain conditions. Without adopt-ing such measure, the impact of Covid-19 no ner work would have been far worse und on the next page Inntin

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'Café y Teoremas' is a weekly publication coordinated by the ICMAT and published in the section entitled Materia of the El Pais daily newspaper. This space is devoted to mathematics and the context in which mathematics is set, where researchers, members and collaborators of the centre give an account of the latest developments in the discipline, as well as sharing the points of confluence between mathematics and other social and cultural expressions. 38 articles appeared in 2021.

News

The ICMAT regularly publishes news on its website about the scientific and outreach activity conducted at the centre. In 2021, 28 news items were published.

Blog

The ICMAT Blog provides a platform on the website for the dayto-day activity at the centre, as well as for sharing information regarding mathematics and the mathematical community. In 2021, 30 articles appeared on this blog.

Social networks

The ICMAT maintains active profiles on the main social networks. The number of followers as of December 2021, is shown below:

- Facebook: 31 511 followers, 29 844 'likes'
- Twitter: 29 239 followers
- Instagram: 589 followers
- YouTube: 2860 subscribers; 65 025 views

An average of three different contents are usually posted every day on Facebook and Twitter, dealing with current mathematical issues about both the ICMAT occasionally and in general, and exclusively about the ICMAT on Instagram. Videos made by the ICMAT are uploaded onto YouTube.

OUTREACH ACTIVITIES

Mathematics at the Residencia

Mathematics at the Residencia consists of a series of talks by internationally renowned speakers on the public understanding of mathematics. It is organized by the ICMAT in collaboration with the CSIC Vice-presidency of Organization and Scientific Culture and the Residencia de Estudiantes of Madrid.

In 2021, the following talks were organised:

"Las matemáticas del déjà vu" (online)

Speaker: Amie Wilkinson (Chicago University)

Date: 6 May 2021

Web



"Por el giro de una aguja" Speaker: Antonio Córdoba (ICMAT-UAM) Date: 28 September 2021

Web



"European Researchers' Night"

This yearly activity is aimed at bringing the general public closer to researchers in person in a festive and entertaining way in order to show the benefits they provide for society and their influence on daily life. Researchers' Night is associated with the European celebration of this event.

In 2021, the European Researchers' Night was celebrated on 24th September. The ICMAT participated in the feria organized by the Comisión Intercentros in Jardín Tropical de la Estación Madrid-Puerta de Atocha: "El tren de la ciencia para en Atocha" with the following workshopS:

"Aprende matemáticas jugando con el ICMAT", given by David Martín (ICMAT-CSIC) and Alexandre Anahory (ICMAT).



Image:

Estudia

Escape-road: "A la búsqueda de las científicas Nobel y no Nobel", coorganisated together with the Comisión de Igualdad Intercentros CSIC+UAM.

Web



Science in Action

Science in Action is a competition based on innovative ideas for bringing science closer to the general public. Those selected in the first phase show their proposals live in a grand final that becomes a great celebration of science. Together with other scientific institutions, the ICMAT is participating in the organization of this dissemination activity. The 2021 competition took place on October 1-3 in Atarfe (Granada).

Science Week

The Science and Technology Week is one of the leading events in social communication of science and technology held in Spain. The ICMAT has participated in this scheme since 2009 by programming conferences and dissemination workshops addressed to all types of audiences. The main objective of these activities has been to improve the social perception of mathematics by revealing its surprising, unexpected and amusing features as well as those most closely related to society in general.

On 11 November 2021, the Institute organised two activities, one of them for secondary school students and the other for general public:

Conference: "Matemáticas para descifrar los misterios • de los fluidos", Diego Córdoba (ICMAT-CSIC)



Conference: "Coches autónomos, ética y matemáticas", David Ríos (ICMAT-CSIC) y Roi Naveiro (ICMAT-CSIC)



Miradas Matemáticas Collection

Miradas Matemáticas consists of a series of books launched in 2017 and combining mathematical outreach and didactics, designed to bring research closer to secondary school and baccalaureate teachers. The books in the collection are produced by the ICMAT, the Spanish Federation of Mathematics Teachers (FESPM) and the publisher Los Libros de la Catarata.

The following volumes were published in 2021:

• Aventuras STEAM, Manuel García Piqueras (consultant, secondary teacher and UCLM). February 2021. ISBN: 978-84-1352-153-4.



La gran familia de los números, Raúl Ibáñez Torres (UPV-EHU). May 2021. ISBN: 978-84-1352-225-8.





• <u>Azar y Probabilidad en matemáticas</u>, Santiago Fernández. July 2021. ISBN: 978-84-1352-274-6.

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 <u>Matemáticas y literatura</u>, Marta Macho-Stadler (UPV/EHU). September 2021. ISBN: 978-84-1352-301-9.

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Audiovisual communication

The ICMAT Mathematical Culture Unit (UCMAT) produces mathematical culture (public talks, interviews, about mathematics and art, etc.), equality (talks, activities, interviews, etc.), institutional, dissemination of calls and scientific videos (workshops, colloquiums, seminars, etc.) that are posted on the <u>ICMAT YouTube channel</u> and on social media. 23 videos were published on YouTube in 2021. Also, the ICMAT uploads to its YouTube channel the talks of Matemáticas en la Residencia, with the allowance of the Residencia de Estudiantes, host of this audiovisual material.

On the whole, the ICMAT has increased its audiovisual activity due to the pandemic; most of the activities were online or in hybrid format (online and in-person) in 2021, although not all of them were recorded and uploaded to ICMAT social media or YouTube.



Graphic communication

From the ICMAT Mathematical Culture Unit, posters are produced to announce the scientific activities of the center, which follow the institutional line of the ICMAT, and facilitate the transmission of information directed to the research community and the general public.

The ICMAT organizes diverse activities every week, for which individual posters are produced and distributed by the ICMAT Mathematical Culture Unit.



13.Equality actions

The number of women researchers engaged in the field of mathematics is still far below that of men, and the further that researchers progress in their professional careers the more this gap increases. The ICMAT is committed to equal opportunities for all and believes that mathematical talent is distributed equally without regard to sex (neither gender, nor race, nor geographical location), so the current situation signifies the loss of great minds for science and constitutes a state of affairs that can and must be remedied. To that end, in 2016 an action plan was launched by the ICMAT board and the Severo Ochoa programme, executed through the centre's Gender Commission (now, Equality Commission), which demonstrates the institutional commitment of the ICMAT to equality and diversity.

The **CSIC** has awarded in 2021 its Seal of Accreditation for Gender Equality 2021 to the ICMAT, after it gained the "highest score from the panel," as stated in the official announcement of the decision, in which it was also stated that "it met the requirements set out in the National Plan for Equality" and highlighted "the commitment of both the management and the personnel of the institute in matters of equality." Likewise, the Institute for Environmental Diagnosis and Water Studies (IDAEA) and the Institute of Marine Sciences (ICM) were also distinguished with an honourable mention.

This distinction is also endowed with 5000 euros for the development of initiatives promoting gender equality. The ICMAT hired a person with this money to set up a research project, together with the Instituto de Políticas y Bienes Públicos del CSIC, to know the reasons why there are so few women studying the degree in Mathematics and doing a PhD.

In May 2021, the ICMAT Equality Committee organised and held online <u>the II Meeting on Gender Equality of the Alliance between</u> <u>Severo Ochoa centres and María de Maeztu units</u> (SOMMa).

This event reunited people who work for reducing the gender gap in science and STEM areas. The main speaker in this activity was Donna Ginther, a distinguished professor and director of the University of Kansas Institute of Policy and Social Research (USA).

Ana Bravo, chairperson of the ICMAT Equality Committee; José María Martell, director of the ICMAT; and María Blasco, director of the Spanish National Cancer Research Centre (CNIO) and chairperson of SOMMa, took part in the opening table.

There was celebrated also a round table, moderated by Patricia Fernández de Lis, journalist in *El País*, with Rosina López-Alonso the vice-president of Organization and Institutional Relations of the CSIC; Zulema Altamirano, the director of the Women and Science Unit of the Ministry of Science and Innovation; and María Blasco.

Noelia Vera, state secretary for Equality and to Combat Gender-based Violence, closed the event. This activity was streamed on the ICMAT YouTube channel where is <u>available</u>.

In early 2021, the **ICMAT became an institutional member of the European Women in Mathematics (EWM)**. The main objective of the EWM is to increase the presence of woman in mathematics. For that purpose, different initiatives have been undertaken to encourage the pursuit of this discipline among women students, to support women in their careers, to contribute to setting up a network of specialists in the field and to make the presence of woman more visible in mathematics. Founded in 1986, EWM has some one hundred members and 33 co-ordinators in different European countries. It organizes an annual general assembly and a summer school. Furthermore, it also publishes two newsletters every year as well as having its own website and a Facebook page. Thanks to the contributions made by its members, it sustains these initiatives, especially its travel grants, as well as round-table discussions and the running of communication platforms.

In 2021, the <u>Equality Commission</u> consisted of the following members: Ana Bravo (ICMAT-UAM, chairperson); Javier Aramayona (ICMAT-CSIC); Eva Gallardo (ICMAT-UCM); Marina Logares (UCM) Marta Macho-Stadler (UPV/EHU); David Martín (ICMAT-CSIC); Catalina Martínez (IPP-CSIC); Laura Moreno (ICMAT-CSIC) and Ágata A. Timón (ICMAT-CSIC). With the collaboration of other ICMAT members and of other institutions, this Commission devised, executed and evaluated the actions of the ICMAT Strategic Gender Plan.

The Equality Commission organized or collaborated with the following activities in 2021:

Science by Women programme. Fundación Mujeres por África (FMxA)



For seven consecutive years, the ICMAT has participated in the <u>Science by Women programme</u> belonging to the Fundación Mujeres por África (Women for Africa Foundation, FMxA), the aim of which is to promote the access of African women to science and technology; to support them in their research careers; to highlight their achievements; to promote their leadership in the international scientific community, and to help them strengthen the capacities of their research groups in their different countries of origin. Thanks to this project, the ICMAT welcomes women from African countries who are selected to come to the centre for six months to collaborate with ICMAT researchers in accordance with their fields of research.

In the 2020 edition (6th), Fagueye Ndiaye (Senegal) was elected, and she worked with Daniel Faraco (ICMAT-UAM) and his group in the ICMAT from May 2021. In the 2021 edition (7th), Narjisse Amahjour (Morocco) was elected to join the ICMAT in 2022.

#STEMatEsElla

The ICMAT Severo Ochoa project, the Higher Institute for Internet Development (ISDI) and the University of Oviedo Chair of Analytical Intelligence sponsor the third edition of the #steMatEsElla programme, inaugurated at the start of the 2020/2021 course. It is run by the Asociación Española de Ejecutiv@s y Consejer@s (Spanish Association of Executives and



Councellors - EJE&CON) and the Real Sociedad Matemática Española (Royal Spanish Mathematical Society - RSME), with the collaboration of the ICMAT and the Basque Center for Applied Mathematics (BCAM).

#steMatEsElla is a scheme for promoting the professional scientific and business careers of women degree students and female master and PhD students of mathematics as well as other related disciplines (grouped under the acronym CTIM). It combines mentoring, coaching, webinars and visibility of reference points, while also working on soft skills. The aim is to put women students into contact with STEM professionals, both in the academic sphere (female researchers and teachers belonging into the RSME and the ICMAT) and in the business sector (EJE&CON executives and counsellors) by means of regular tutorial sessions during the academic year, the Ernst & Young was collaborator in this scheme in 2020-2021.

Other than the tutorial sessions, the <u>Dialogues</u> are one of the actions of this programme. It is based on the <u>Diálogos de género</u> <u>y ciencia</u>, organized by the ICMAT from 2016 to 2019. The aim of these dialogues is to bring leading exponents of STEM subjects into closer contact with students in the field in order to provide role models and to stimulate the exchange of thoughts and opinions in a relaxed and familiar environment. In 2020, the series of talks was inaugurated by Nuria Oliver, one of the foremost specialists in artificial intelligence and data science in Spain.

In 2021, the following dialogues took place online:

 25/02/2021. "¡Tú también puedes!" ("You can do it too!"), Silvia Bruno (Innovación de Red Eléctrica) and María Jesús Carro (Universidad Complutense de Madrid).



07/05/2021. "Big Data. Del mundo académico al professional", Elena Gil Lizasoain (Telefónica IoT & Big Data) and Elena Fernández (Universidad de Cádiz, RSME).



"She Does Maths", ICMAT Newsletter

<u>She Does Maths'</u> is a permanent section of the ICMAT Newsletter in which a portrait of a women mathematician (preferably at her place of work) is given, together with a brief description of her research work. This content is also available on the blog '<u>Mujeres con Ciencia</u>'. On the basis of this section of the Newsletter, posters in A3 are prepared that are later attached to the doors of the science faculties and mathematics departments of the three Madrid universities of which the Institute forms part: UAM, UCM and UC3M.

In 2021, <u>María Xosé Rodríguez-Álvarez</u> (BCAM) and <u>Tatiana Toro</u> (Universidad de Washington) were the protagonists.



February 11th commemoration, International Day of Women and Girls in Science

The ICMAT has joined in celebrating <u>11 February</u>, <u>International</u> <u>Day of Women and Girls in Science</u> since 2018. In 2021, the Institute organised different activities:

• 11 February 2021. "Constelaciones matemáticas", by Marta Folgueira (Universidad Complutense de Madrid). Online talk-workshop for primary students.



"¿Qué matemática te ha inspirado más?". A series of videos published on the ICMAT social media with researchers speaking about their favourite female mathematician.



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Activities coorganized together with the Comisión de igualdad intercentros CSIC+UAM:

- 9 February 2021. Colloquium online: "La increíble ciencia detrás de los agujeros negros, Gravedad y el Premio Nobel de 2020", María José Rodríguez (IFT-USU).
- 11 February 2021. Colloquium online: "Dos investigadoras premiadas con el Premio Nobel de Química de 2020 como promotoras de la revolución CRISPR", Lluís Montoliu (CNB-CSIC).
- 10, 11, 13 February 2021. Escape-road: "A la búsqueda de las científicas Nobel y no Nobel".

May 12, Celebrating Women in Mathematics

For the second year running, the Day of Women in Mathematics was held on 12 May, the birthday of the Iranian mathematician Maryam Mirzakhani, the only woman to win a Fields Medal and who sadly died in 2017. Throughout the month, and with the slogan Celebrating Women in Mathematics, a series of activities were organized all over the world - many of which, given the circumstances, were virtual events - with the aim of highlighting the work of women mathematicians, profiling outstanding figures and helping in the struggle to close the gender gap that exists in the discipline. This second edition enjoyed a considerable following, with more than 80 events registered on the website set up for the celebration and thousands of views of the documentary Secrets of the Surface. The Mathematical Vision of Maryam Mirzakhani in 124 different countries, according to the organizers of the May 12 initiative. The idea for this celebration came from the Women's Committee of the Iranian Mathematical Society and was approved at the World Meeting for Women in Mathematics (WM)², one of the satellite congresses that was held at the last International Congress of Mathematicians (ICM), held in Río de Janeiro (Brazil) in 2018.

In 2021, the ICMAT organized the following activity:

• A meeting open to the public via Instagram Live with two women researchers and ICMAT Members: Laia Domingo and Manuela Gamonal. Moderated by Laura Moreno Iraola (ICMAT), the researchers talked about their careers, mathematics, research areas, interests... The video is available on the ICMAT (@_icmat) Instagram profile.





Production:

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