



annual report 2019













www.icmat.es



Production:

Instituto de Ciencias Matemáticas (ICMAT) C/ Nicolás Carrera nº 13-15 Campus de Cantoblanco, UAM 29049 Madrid ESPAÑA

Text: ICMAT personnel

Editing:

- Mónica Castresana
- Esther Fuentes
- Jacob Goodman
- José María Martell
- Laura Moreno Iraola
- Fernando Quirós
- Ágata Timón García-Longoria

Front page: Laura Moreno Iraola

Layout: Equipo globalCOMUNICA

Translation: Jeff Palmer

INDEX

1.	Introduction	04
2.	The ICMAT in figures	05
3.	Personnel	07
4.	Scientific results	14
5.	Awards and distinctions	23
6.	Funding and research projects	25
7.	Severo Ochoa Programme	28
8.	Scientific activities	28
9.	Thesis	36
10	.Institutional networks	37
11	. Transfer activities	
12	.Communication and outreach activities	41
13	.Gender Commission	46

1. Introduction: 2019, a year of changes

José María Martell, ICMAT director

2019 was notable for being the last year of the second ICMAT Severo Ochoa project. Furthermore, the end of this cycle was accompanied by a great deal of scientific activity at the centre. It is worth mentioning the three thematic programmes that entailed a non-stop flow of visitors, some of whom are international experts, as well as the participants in their schools, conferences, workshops, seminars and so on. The "Operator Algebras, Groups and Applications to Quantum Information" programme was held in the spring, and the "Current trends in Geometric Methods in Natural Sciences" programme in the autumn. The third programme in 2019 was devoted to "Quantum Information Theory," within the framework of the "Ignacio Cirac" ICMAT Laboratory. In addition to all the activities belonging to these research trimesters, the centre hosted 25 congresses and schools and 11 courses, conferences and working groups.

The conclusion of this Severo Ochoa project led to the need to draw up a new proposal for the next four years. Consequently, during autumn 2019 the ICMAT concentrated much of its energie on the preparation of its application for a third Severo Ochoa programme, headed by Diego Córdoba. Both the researchers and the management team belonging to the different work groups who collaborated on the application devoted their efforts to designing the future of the Institute. As on previous occasions, the proposal submitted sets out a strategy whose aim is the continued commitment to scientific excellence. It has recently been confirmed that the ICMAT will indeed enjoy its third Severo Ochoa award, which will determine the course and structure of the ICMAT during the coming 2020-2023 four-year period.

In addition, the ICMAT continues to consolidate its prominent position as regards funding from the European Research Council (ERC). At the end of 2019, it was confirmed that Albert Enciso had obtained a Consolidator Grant for the development of his project, the "Analysis of geometry-driven phenomena in fluid mechanics, PDE's and spectral theory (FLUSPEC)." Moreover, the "Quasiconformal Methods in Analysis and Applications (QUAMAP)" project, codirected by Kari Astala (University of Aalto, Finland), Daniel Faraco (ICMAT-UAM), Keith Rogers (ICMAT-CSIC) and Xiao Zhong (University of Helsinki, Finland), received an Advanced Grant. The first three of these researchers belong to the ICMAT "Kari Astala" Laboratory, which is funded through the second ICMAT Severo Ochoa programme. Finally, Javier Gómez-Serrano, who completed his thesis at the ICMAT under the supervision of Diego Córdoba, obtained a Starting Grant. The application for Gómez-Serrano's project was made at the ICMAT, but will finally be conducted at the University of Barcelona. Still on the subject of European funding, in 2019 Javier Ramos (ICMAT-CSIC) obtained one of the grants from the European Union Marie Skłodowska-Curie programme to develop his project, "A multilinear approach to the restriction problem with applications to geometric measure theory, the Schrödinger equation and inverse problems (RESTRICTIONAPP).'

The excellence of the scientific staff at the ICMAT was also recognized with various prizes in 2019. David Pérez García (ICMAT-UCM) was awarded the 3rd Banco de Sabadell Prize for Science and Engineering for his contributions to quantum information, Banach spaces and operator theory. Furthermore, researchers Carlos Mudarra and María Ángeles García Ferrero, both former PhD students at the ICMAT, received the 2019 Vicent Caselles Prize for Mathematical Research from the *Real Sociedad* *Matemática Española* (RSME) and the BBVA Foundation, which is awarded to young male or female researchers under the age of 30 who are still in the early stages of their careers.

Lastly, in 2019 the Institute underwent restructuring in several ways: in its permanent research personnel, in the structure of its research groups and its management team. The early part of the year saw the conclusion of the process of appointments of permanent personnel to the Autonomous University of Madrid (UAM), the Carlos III University (UC3M) and the Complutense University, which in accordance with our Internal Regulations must take place every four years, followed by an extraordinary process for permanent members of the UAM. The result of the process is a new configuration of staff at the centre, which consists of 43 research personnel (18 from the CSIC, 12 from the UAM, 3 from the UC3M and 11 from the UCM).

At the end of April, a debate was held in the ICMAT's new Scientific Faculty about the research groups with whom the CSIC organizes its centres. In the case of the ICMAT, since it is a joint centre consisting of four institutions, this model has created a lack of homogeneity as far as the size of the groups and the variety of subject matter are concerned. Thus, research teams containing a large number of researchers, grouped across a broad range of subjects, exist side by side with atomized groups whose subject matter is more restricted. In order to achieve a more homogeneous model, the Scientific Faculty approved a policy for the ICMAT to be organized and structured around the following research groups:

- Algebra and Geometry
- Mathematical Analysis and Differential Equations
- Applied Mathematics

Each of these groups will address a broad variety of research topics; they are all of a similar size and nourish the different CSIC research groups. Moreover, this new way of working enables the scientific strategy of the centre to be decided more efficiently and with greater coordination.

During the autumn of 2019, the post of director of the ICMAT became vacant due to the retirement of Antonio Córdoba, whom I replaced on an interim basis since I was the deputy director. An election process was then undertaken in which I was the sole candidate for the directorship. After a vote held at the Scientific Faculty, the ICMAT Board referred this candidacy to the Steering Committee, which in turn approved the nomination of a single candidate. This nomination process was completed at the beginning of 2020.



José María Martell, ICMAT director



2. The ICMAT in figures

Personnel



Scientific activities

- Thematic research programmes: 3
- Congresses and schools: 25
- Courses, conferences and work groups: 11
- Colloquia. Total: 11
 - a) UAM-ICMAT Colloquium: 5
 - b) ICMAT-UCM Colloquium: 3
 - c) Special Colloquium: 3
- Seminars. Total: 200
- Thesis: 17
- JAE School 2019: 1

Communications

- Press releases: 19
- News stories: 41
- Articles:
 - 'Café y Teoremas': 39
 - ICMAT Blog: 14
- ICMAT Newsletter: 1
- Followers on social media (in December 2019)
 - 🚹 Facebook: 28 034 followers, 27 092 'I like'
 - y 🛛 Twitter: 24 950 followers
 - Instagram: 2900 followers
 - YouTube: 1351 subscribers; 49 646 views



Outreach materials: 11

Publications





ICMAT Funding 2019

- Projects: 2 051 118,63 €
 - Source:
 - 1. Private company: 385 828,15 €
 - 2. Europe: 1 151 282,48 €
 - 3. Out of EU: -
 - 4. Spain: 514 008 €
 - 5. Others: 24 000 €
 - Total public funding: 2 011 990,48 €

□ Competitive public funding:

FP 7/ H2020 (EU)	International (without EU)	National	Regional (Spain)	Others
1 151 282,48 €1		191 008 € ²	299 000 € ³	24 000 €4

1. Trustonomy (206 500 €); QUAMAP (771 850 €); RESTRICTIONAPP (17 932,48 €) 2. PGC2018-097286-B-I00 (90 508 €); EUR2019-103821 (75 000 €) 3. IND2018/TIC-9901 (64 000 €); S2018/TCS--4342 (200 000 €); PEJD-2018-POST-TIC-9375 (35 000 €)

4. CSIC LINKA20079 (24 000 €)

□ Non-competitive public funding:

International	National	Regional (Spain)	Others
	372 200 €⁵		

5. ICMAT regular funding (from the four institutions: CSIC, UAM, UC3M and UCM).

- Total private funding: 385 828,15 €

International	National
385 828,15 €⁴	

6. AXA – ICMAT Permanent Chair in Adversary Risk Analysis (882 000 € received; 147 000 € per year); "La Caixa" Foundation (1 969 112,3 € received).

ICMAT Expenditure 2019

- Personnel expenditure:
 - ICMAT: 791 475,89 €
 - Cofounding: 33 134,14 €
- Activities:
 - Workshops, conferences and schools: 31 691,97 €
 - Thematic research programmes: 93 627,35 €
 - Seminars: 16 428,96 €
- Others (infrastructure, subscriptions, library, fungible, material inventory, training, representation): 47 891,34 €
- Communication and outreach: 38 013 €
- Master scholarships: 34 831,43 €
- ICMAT Labs and Distinguished Professors: 32 678,79 €
- Travel expenses: 26 740,15 €
- Introduction to research scholarships programme: 14 321,06 €
- Visitors programme: 5988,52 €

Total expenses: 1 166 822,6 €



In 2019, more than 260 scientific activities were held at the ICMAT.



3. Personnel

In 2019, the process of appointing permanent research personnel of the universities to the ICMAT was completed. The applications were studied by a Joint Committee chaired by O. García-Prada (ICMAT-CSIC) -proposed by the management-, E. Miranda (Technical University of Catalonia) and J. Parcet (ICMAT-CSIC) -proposed by the ICMAT Board-, J. A. Carrillo de la Plata (Imperial College, UK) and F. Santos (University of Cantabria) -proposed by the UAM-, José Niño Mora (UC3M) and J. Sanz Serna (UC3M) -proposed by the UCRM-, and M. J. Carro (University of Barcelona) and M. Castrillón (UCM) -proposed by the UCM-. This group of experts drew up a proposal that was ratified by the ICMAT Board and referred to the Steering Committe, which gave it its final approval. The result was a broad overhaul of appointments and the incorporation of four new members: J.F. Fernando (UCM), M. Mañas (UCM), C. Rascón (UC3M) and I. Villanueva (UCM). On the other hand, the following researchers did not renew their affiliation: M. Castrillón (UCM), E. Colorado (UC3M), E. Girondo (UAM), A. Gómez-Corral (UCM), D. Gómez-Ullate (UCM), E. González (UAM), P. D. González (UCM) and F. Marcellán (UC3M), to whom we express out gratitude for their work over recent years.

The final result of this process left a considerable gap between the theoretical percentage of participation in the ICMAT by each of the institutions and the real percentage of the permanently assigned personnel. For that reason, the Steering Committee decided to open an extraordinary process for permanent members of the UAM, which concluded with the appointment of M. Bonforte, M^a M. González, and F. Quirós. C. Palazuelos (UCM), who had joined the permanent personnel of the UCM on conclusion of the process, was also added to this list. These new appointments caused the actual percentage to become more in line with the theoretical percentage, although there still exists a deficit of UAM members that we hope will be remedied in the near future.

At present, the composition of the staff at the centre is a follows: 43 research staff, of whom 18 belong to the CSIC, 12 from the UAM, 11 from the UCM and 3 from the UC3M.

Furthermore, 33 post-doctoral researchers joined the Institute during this year (from both the CSIC and the universities), in addition to 19 new pre-doctoral researchers and one member of the administrative team. Likewise, seven grants for a ten-month period were obtained for Master students and two JAE grants for the introduction to CSIC research.

On the negative side, however, it is necessary to mention the termination at the end of the year of contracts for all personnel hired through the UAM Foundation (FUAM), which formed part of the administrative office at the Institute and of the CFTMAT management team.



At present, the composition of the staff at the centre is 60 postdoctoral researchers, 46 permanent researchers, 45 predoctoral researchers and 16 staff members.

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: <u>Applied mathematics</u>

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
- 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
- Orlando Villamayor

Members

- Javier Aramayona
- Giovanni Bazzoni
- Federico Cantero
- Leonardo Colombo
- Mario García
- Daniel Macías
- Carolina Vallejo

Doctoral students

- Alexandre Anahory
- Julio Aroca
- Guillermo Barajas
- Miguel Ángel Berbel
- Jan Boschheidgen
- Andoni de Arriba
- Celia del Buey
- Dahyana Eugen Farias
- Eduardo Fernández
- Raúl González
- Francisco Javier González
- Jacob Goodman
- Manuel Lainz
- Xabier Legaspi
- Diego López
- Hang Lu
- Manuel Mellado
- Samuel Ranz
- Álvaro Rodríguez
- Álvaro Romaniega

Associated members

- Yago Antolín
- María Barbero
- Juan Carlos Marrero
- Eva Miranda
- Edith Padrón
- Ana José Reguera
- Cristina Sardón

Master students

- Eduardo de Lorenzo
- Manuela Gamonal
- Jorge Hidalgo
- Roberto Téllez
- Wei Zhou



In 2019, this group organised the following seminars weekly:

- Group theory Seminar
- Number theory Seminar
- Geometry Seminar
- Geometric mechanics and control Seminar
- Commutative algebra, algebraic and arithmetic geometry Seminar

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.

The following researchers are part of this group:

Faculty

- José María Arrieta
- Daniel Azagra
- 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

Moreover, it organised a study group on Euler systems and the "<u>Groups in Madrid"</u> workshop (November 28-29, 2019).

The following CSIC research groups are involved in Group A:

- GROUP 4: Algebraic geometry and mathematical physics
- <u>GROUP 5: Differential geometry and geometric mechanics</u>
- GROUP 8: Group theory
- <u>GROUP 9: Number theory</u>
- Rafael Orive
- Javier Parcet
- Fernando Quirós
- Aníbal Rodríguez
- Keith Mckenzie Rogers
- Alberto Ruiz
- Pedro Tradacete
- Dmitry Yakubovich

Members

- Davide Barbieri
- Pablo Candela
- José Manuel Conde
- Elena di Lorio
- Nastasia Grubic
- Matthew Blair Hernández
- Teresa Elvira Luque
- Ana Primo
- Javier Ramos
- Daniel Seco
- Fan Zheng

Doctoral students

- Glenier Lázaro Bello
- Antonio Ismael Cano
- Víctor Cañulef
- Miguel García
- Diego González
- Luis Martínez
- Francisco José Mengual
- Miguel Monsalve
- Jesús Ocáriz
- Elena Salguero
- Omar Sánchez
- Jaime Santos

Associated members:

Antonio Córdoba

Master students:

- Pablo Hidalgo
- José Manuel Navarro
- David Rello
- Eduardo Tablate

In 2019, this group organised the following seminars weekly:

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 adversaries 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

- Marco Antonio Fontelos
- Alberto Ibort
- Fernando Lledó
- Carlos Palazuelos

- Analysis and applications Seminar
- PDE's and fluid mechanics Seminar
- Number theory Seminar

It also participated in the organisation of the study group on Euler systems, previously mentioned.

The following CSIC research groups are involved in Group B:

- GROUP 1: Mathematical analysis
- GROUP 2: Differential equations and applications
- GROUP 9: Number theory
- David Pérez
- Carlos Rascón
- David Ríos
- Ignacio Villanueva

Members

- Jared Aurentz
- Jezabel Curbelo
- Fabio di Cosmo
- David Gordo
- Jose Antonio Jiménez
- Alex Kosgodagan
- Juan Manuel Pérez

Doctoral students

- Patricia Contreras
- John Stewart Fabila
- Bruno Flores
- Victor Adolfo Gallego
- Guillermo García
- José Garre
- Si Liu
- Luis Diego Martínez
- Adrián Martínez
- Roi Naveiro
- Simón Rodríguez
- Alberto Ruiz de Alarcón

Associated members

Carlos Escudero

In 2019, this group organised the following seminars regularly:

- Applied mathematics Seminar
- DataLab Seminar
- Q-Math Seminar

The following CSIC research groups are involved in Group C:

- GROUP 3: Statistics, probability and operations research
 (SPOR)
- <u>GROUP 6: Mathematics of quantum information:</u>
 <u>foundations and applications</u>
- GROUP 7: Mathematical modelling and simulation



3.2. Executive team and board

ICMAT Executive team

Antonio Córdoba (director) [until August 2019]

José María Martell (deputy director [until August 2019] and acting director [since September 2019])

Francisco Presas (head of the Department of Fundamental Mathematics)

David Pérez García (head of the Department of Applied Mathematics)



Antonio Córdoba



José María Martell

ICMAT Board







Francisco Presas

David Pérez García





Javier Parcet



Daniel Peralta



Miguel Anchuelo

3.3. ICMAT External Scientific Advisory Committee

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 EPSRC 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 Univeristy. 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 funding from the Severo Ochoa project, for a further year the ICMAT is able to count on its technical support team, which enables the Institute to develop its own internationalization, knowledge transfer, outreach and gender programmes, among others.

The main tasks and aims of the **Administrative Office** consist in providing technical support to CFTMAT management and administration as well as to the research staff and also visitors who come to the Institute to attend different events. Among these tasks, it is worth mentioning the management and processing of billing arising from the activities conducted at the centre; the processing of expenses and settlements concerning the researchers themselves as well as visitors; the active participation in the organization of schools and conferences held at the Institute; support for the Severo Ochoa project regarding the justification of the assistance for and expenses incurred by the centre's research personnel for any procedure or activity that may be required.

Throughout 2019, the **ICT Office** provided internet support for researcher personnel in the creation of websites for events, content updates, corporative mail and the development of intranet applications, as well as the management of purchases of ICT material. Likewise, together with the Institute of Theoretical Physics, it also co-organized the "Software Carpentry" workshop, held between November 28th and 30th, which was aimed at personnel belonging to the centre at all levels, and covered ICT concepts and tools applied to research. Furthermore, more than twenty ICMAT members worked with the cluster, which consists of more than 1,200 computing processors and six GPU, making use of 60 % of the computing capacity. In addition, the infrastructure acquired thanks to the 100,000 euros granted in 2018 by the ERDF (European Regional Development Fund) was set up, for the purpose of extending the computing capability of the ICMAT.

Also in 2019, the **Communication and Outreach Office** continued its usual activity by organizing a dozen face-to-face outreach events, issuing more than 40 press releases and a similar number of articles in <u>Coffee and Theorems</u>', the section in the daily newspaper *El País* devoted to mathematics, as well as the ICMAT newsletter and a permanent presence on different social networks. The third and final edition of the <u>My favourite women scientist</u> project was also held last year, and the second season of the <u>Mathematical revolutions</u>' cartoon videos was also launched, this time within the framework of the <u>City Science</u>' project, a local scientific outreach programme co-ordinated by the *Consejo Superior de Investigaciones Científicas* (CSIC) and the *Fundación Española para la Ciencia y la Tecnología* (FECYT).

During the same period, the second ICMAT Severo Ochoa project was completed, which also signalled the submission for the third accreditation as a centre of excellence, coordinated by the **Severo Ochoa Office** together with the collaboration of a broad spectrum of members belonging to the Institute. Over this same period of time, the office provided technical and administrative support for all the activity financed through the SO project (details of which can be found in Section 7, page 28), notably the three thematic research semesters held at the centre throughout the year.

The **European Office** has assisted ICMAT researchers in their applications to international calls issued by public and private entities. In 2019, ICMAT members received funding for five projects in the H2020 programme frame: two new Advanced Grants and one Consolidator Grant of the European Research Council (ERC), an innovation project for the H2020 Industrial Leadership scheme and one Marie Skolodowska-Curie action. In addition to the projects already under way, the Office organized informative sessions on European opportunities and drew up several informative guides for the application of projects.

In addition to these offices, Marta Sanz González (ICMAT-CSIC) was also appointed in an administrative role for the David Ríos AXA Project.

4. Scientific results

In 2019, the scientific production of ICMAT researchers has exceeded 180 publications. Of these, 42 appear in the first decile, according to the *WOS Article Influence Score*. On the other hand, if we look at the Impact Factor of *WOS JCR*, we have 80 in Q1 and 27 in D1. Similarly, *SCOPUS Scimago SJR* returns a total of 127 items in Q1, and 67 in D1.

The articles of the first decile, following the WOS Article Influence Score are:

- Alonso-Orán, Diego; Bethencourt de Leon, Aythami (2019). "On the well-posedness of stochastic boussinesq equations with transport noise." *Journal of Nonlinear Science*, *30*, 175 - 224.
- Ao, Weiwei; Chan, Hardy; Delatorre, Azahara; Fontelos, Marco A.; González, Maria del Mar; Wei, Juncheng (2019).
 "On higher-dimensional singularities for the fractional Yamabe problem: A nonlocal Mazzeo-Pacard program." Duke Mathematical Journal, 168, 3297 - 3411.
- Aparicio-Arroyo, Marta; Bradlow, Steven; Collier, Brian; García-Prada, Oscar; Gothen, Peter B.; Oliveira, Andre (2019). "SO (p, q) -Higgs bundles and higher Teichmüller components." *Inventiones Mathematicae*, 218, 197 - 299.
- Aurentz, Jared L.; Austin, Anthony P.; Benzi, Michele; Kalantzis, Vassilis (2019). "Stable computation of generalized matrix functions via polynomial interpolation." *Siam Journal On Matrix Analysis and Applications*, 40, 210 – 234.
- Azagra, Daniel; Dobrowolski, Tadeusz; García-Bravo, Miguel (2019). "Smooth approximations without critical points of continuous mappings between Banach spaces and diffeomorphic extractions of sets." Advances In Mathematics, 354.
- Azagra, Daniel; Mudarra, Carlos (2019). "Smooth convex extensions of convex functions." *Calculus of Variations and Partial Differential Equations*, 58.
- Benyi, Arpad; Martell, José María; Moen, Kabe; Stachura, Eric; Torres, Rodolfo H. (2019). "Boundedness results for commutators with BMO functions via weighted estimates: a comprehensive approach." *Mathematische Annalen*, 376.
- Biswas, Indranil; García-Prada, Oscar; Hurtubise, Jacques (2019). "Higgs bundles, branes and Langlands duality." *Communications In Mathematical Physics*, 365, 1005 - 1018.
- Burgos Gil, José Ignacio; Goswami, Souvik (2019). "Higher arithmetic intersection theory." *Advances In Mathematics*, 346, 569 664.
- Burgos Gil, José Ignacio; Philippon, Patrice; Rivera-Letelier, Juan; Sombra, Martín (2019). "The distribution of Galois orbits of points of small height in toric varieties." American Journal of Mathematics, 141, 309 - 381.
- Casals, Roger; del Pino, Álvaro; Presas, Francisco (2019). "Loose Engel structures." *Compositio Mathematica*, 156, 412 434.
- Casals, Roger; Murphy, Emmy; Presas, Francisco (2019). "Geometric criteria for overtwistedness." *Journal of The American Mathematical Society*, 32, 563 - 604.
- Castro, Ángel; Faraco, Daniel; Mengual, Francisco (2019). "Degraded mixing solutions for the Muskat problema." *Calculus of Variations and Partial Differential Equations*, 58.

- Castro, Ángel; Córdoba, Diego; Lear, Daniel (2019). "Global existence of quasi-stratified solutions for the confined IPM equation." Archive For Rational Mechanics and Analysis, 232, 437 - 471.
- Castro, Ángel; Córdoba, Diego; Lear, Daniel (2019). "On the asymptotic stability of stratified solutions for the 2D Boussinesq equations with a velocity damping term." Mathematical Models & Methods In Applied Sciences, 29, 1227 - 1277.
- Celledoni, Elena; Farré Puiggali, Marta; Hoiseth, Eirik Hoel; Martín de Diego, David (2019). "Energy-preserving integrators applied to nonholonomic systems." *Journal of Nonlinear Science*, 29, 1523 - 1562.
- Chamizo, Fernando; Córdoba, Antonio; Ubis, Adrián (2019). "Fourier series in BMO with number theoretical implications." *Mathematische Annalen*, 376, 457 - 473.
- Colombo, Leonardo Jesús; Goodman, Jacob (2019). "On the existence and uniqueness of Poincaré maps for systems with impulse effects." *Ieee Transactions On Automatic Control*, 65, 1815 – 1821.
- Contreras-Tejada, Patricia; Palazuelos, Carlos; de Vicente, Julio (2019). "Resource theory of entanglement with a unique multipartite maximally entangled state." *Physical Review Letters*, 122.
- Córdoba, Diego; Gómez-Serrano, Javier; Ionescu, Alexandru D. (2019). "Global solutions for the generalized SQG patch equation." *Archive for Rational Mechanics and Analysis*, 233, 1211-1251.
- Cowling, Michael G.; Martini, Alessio; Mueller, Detlef; Parcet, Javier (2019). "The Hausdorff-Young inequality on Lie groups." *Mathematische Annalen*, 375. 93 – 131.
- Curbelo, Jezabel; Duarte, Lucia; Alboussiere, Thierry; Dubuffet, Fabien; Labrosse, Stephane; Ricard, Yanick (2019). "Numerical solutions of compressible convection with an infinite Prandtl number: comparison of the anelastic and anelastic liquid models with the exact equations." *Journal of Fluid Mechanics*, 873, 646 – 687.
- Di Lorio, Elena; Marcati, Pierangelo; Spirito, Stefano (2019). "Splash singularities for a general Oldroyd model with finite Weissenberg number." *Archive for Rational Mechanics and Analysis*, 235, 1589 1660.
- Domínguez-Vázquez, Miguel; Enciso, Alberto; Peralta-Salas, Daniel (2019). "Solutions to the overdetermined boundary problem for semilinear equations with position-dependent nonlinearities." Advances In Mathematics, 351, 718 – 760.
- Enciso, Alberto; García-Ferrero, María Ángeles; Peralta-Salas, Daniel (2019). "Approximation theorems for parabolic equations and movement of local hot spots." *Duke Mathematical Journal*, 168, 897 – 939.



- Enciso, Alberto; Kamran, Niky (2019). "Lorentzian Einstein metrics with prescribed conformal infinity." *Journal of Differential Geometry*, 112, 505 – 554.
- Enciso, Alberto; Luque, Alejandro; Peralta-Salas, Daniel (2019). "Stationary Phase Methods and the Splitting of Separatrices." *Communications In Mathematical Physics*, 368, 1297 – 1322.
- Faraco, Daniel; Lindberg, Sauli (2019). "Proof of Taylor's conjecture on magnetic helicity conservation." *Communications In Mathematical Physics*, 373, 707 738.
- García-Fernández, Mario (2019). "Ricci flow, Killing spinors, and T-duality in generalized geometry." Advances In Mathematics, 350, 1059 – 1108.
- García-Fernández, Mario (2019). "T-dual solutions of the Hull-Strominger system on non-Kähler threefolds." *Journal Fur Die Reine Und Angewandte Mathematik*, 2020.
- García-Prada, Oscar; Ramanan, S. (2019). "Involutions and higher order automorphisms of Higgs bundle moduli spaces." *Proceedings of The London Mathematical Society*, 119, 681 – 732.
- Ge, Jian; Guijarro, Luis; Solórzano, Pedro (2019). "Riemannian rigidity of the parallel postulate in total curvature." *Mathematische Annalen*, 376, 177 – 185.
- Hernández, Matthew (2019). "Mechanisms of lagrangian analyticity in fluids." *Archive For Rational Mechanics and Analysis*, 233, 513 598.
- Jaikin-Zapirain, Andrei (2019). "The base change in the Atiyah and the Lück approximation conjectures." *Geometric and Functional Analysis*, 29, 464 538.
- Jaikin-Zapirain, Andrei; López-Álvarez, Diego (2019). "The strong Atiyah and Lück approximation conjectures for one-relator groups." *Mathematische Annalen*, 376, 1741 – 1793.
- Jaikin-Zapirain, Andrei; Shusterman, Mark (2019). "The Hanna Neumann conjecture for Demushkin groups." *Advances In Mathematics*, 349, 1 28.
- Kastoryano, Michael J.; Lucia, Angelo; Pérez-García, David (2019). "Locality at the boundary implies gap in the bulk for 2D." Communications In Mathematical Physics, 366, 895 926.
- Kubicki, Aleksander M.; Palazuelos, Carlos; Pérez-García, David (2019). "Resource quantification for the no-programing theorem." *Physical Review Letters*, 122.
- Lazar, O; Xue, LT (2019). "Regularity results for a class of generalized surface quasi-geostrophic equations." *Journal de Mathematiques Pures et Appliquees*, 130, 200 – 250.
- Luca, Renato; Rogers, Keith M. (2019). "Average decay of the Fourier transform of measures with applications." *Journal of The European Mathematical Society*, 21, 465 – 506.
- Martell, José María; Mitrea, Dorina; Mitrea, Marius; Mitrea, Irina (2019). "The BMO-Dirichlet problem for elliptic systems in the upper half-space and quantitative characterizations of VMO." Analysis & Pde, 12, 605 720.
- Sauerwein, David; Molnar, Andras; Cirac, J. Ignacio; Kraus, Barbara (2019). "Matrix Product States: Entanglement, Symmetries, and State Transformations." *Physical Review Letters*, 123.

Here are scientific reviews of 15 of these articles:

"On higher dimensional singularities for the fractional Yamabe problem: a non-local Mazzeo-Pacard program"

Authors: Weiwei Ao, Hardy Chan, Azahara de la Torre, Marco Antonio Fontelos, Mar González and Juncheng Wei.

Source: Duke Math. J. 168, Number 17 (2019), 3297-3411.

Date of publication: 2019

<u>Link</u>

Review:

The paper under review falls within the boundary between differential geometry and the analysis of partial differential equations. It consists of 115 pages and is devoted to the construction of singular manifolds with constant fractional (or non-local) curvature. This is a problem that arises in geometrical analysis, since a common method in the geometric classification of manifolds is to find an equivalent constant curvature manifold, which is a model for the geometry.

Non-local curvatures are defined according to the fractional Laplacian on the manifold, which is a non-local operator. From the point of view of analysis, a non-local operator not only sees what is occurring in its immediate surroundings, but also takes into account interactions with distant points. From the geometric perspective one can define a uniparametric family of curvatures with good conformal properties (that is, angle preserving and that generalizes the usual notions of scalar, mean curvature, or the one associated to the Paneitz operator. Each one of these, in turn, provides different geometric and topological information about the manifold that is useful for classification purposes. This notion of curvature comes from the study of the scattering theory in Einstein manifolds, which is originally based on work by John von Neumann, Roger Penrose and Claude R. Le Brunn in 4-dimensional gravitational physics, in connection with Juan Martín Maldacena's AdS/CFT correspondence.

In the paper published in Duke Mathematical Journal one looks for constant curvature manifolds with prescribed singularities. For this construction, the classical "gluing" method is used; that is, one first builds a good model of singularity and then glues it to the original manifold. In the local case, considered in the classical paper¹, the gluing region is easy to control. However, this constitutes the first great difficulty in the non-local case, since the gluing process affects the whole manifold and may disrupt the geometry.

The second major obstacle is the construction of the basic singularity model. One starts by looking for radial solutions that have a singularity exactly at the origin; for this, one needs to solve a non-local ODE. While usual ODEs can be solved by phase plane analysis, in the non-local case this is not possible, since the trajectory at a point depends on what happens far away. There are no existence, uniqueness or continuous dependence theorems for these types of equations, which constitute a completely unexplored field. In our result we have obtained general theory for particular non-local ODE, including Frobenius' Theorem, which characterises the asymptotic development of the solution near the singular points; the study of a quantity with properties similar to the Wronskian of two linearly independent solutions to the homogeneous equation; or the construction of a Green function for the reconstruction of a particular solution to the non-homogeneous equation.

R. Mazzeo, F. Pacard. A construction of singular solutions for a semilinear elliptic equation using asymptotic analysis. *J. Differential Geom.* 44 (1996), no. 2, 331–370.

The main innovation in the proof is the characterization of a non-local ODE as an infinite dimensional system of coupled second-order equations. As a result, if one manages to control this coupling, it is possible to classical ODE theory for a non-local problem.

"SO(p, q)-Higgs bundles and higher Teichmüller components"

Authors: Marta Aparicio-Arroyo, Steven Bradlow, Brian Collier, Oscar García-Prada, Peter B. Gothen and André Oliveira.

Source: Inventiones Mathematicae 218 (2019), 197-299.

Date of publication: 2019

Link

Review:

Given a compact smooth surface S of genus $g \ge 2$, the Teichmüller space of S parametrizes complex structures on S, up to diffeomorphisms of S isotopic to the identity. Riemann's moduli space of projective complex algebraic curves of genus g is obtained as the quotient of Teichmüller space by the mapping class group of S. The Teichmüller space of S can be identified with a topological component of the character variety of the fundamental group of S in PSL(2,R), consisting of Fuchsian representations. This is given by the holonomy of the hyperbolic metric associated to the complex structure, via the uniformization theorem, defining a Fuchsian group. Teichmüller space plays a very important role in many areas of mathematics, including complex analysis, lower dimensional topology, algebraic geometry, hyperbolic geometry, geometric group theory, dynamical systems, etc.

In 1992, Nigel Hitchin, using the theory of Higgs bundles, which he had introduced few years earlier, identified a component of the character variety of the fundamental group of S in PSL(n, R) —and more generally in a split real form of any complex semisimple Lie group—that shared many properties with Teichmüller space. This component, known as Hitchin component, contains actually the usual Teichmüller space and, as Teichmüller space, consists entirely of discrete and faithful representations of the fundamental group. This was proved by François Labourie in 2006, after introducing the important concept of Anosov representation.

Starting around 2000, character varieties of the fundamental group for non-compact Hermitian groups were under investigation. A Hermitian group is the isometry group of a symmetric space which is Kähler. The group PSL(2,R) is both split and Hermitian. Again, new components consisting entirely of discrete and faithful representations were found using Higgs bundle theory and described in various papers involving Olivier Biquard, Steven Bradlow, Oscar García-Prada, Peter Gothen, Ignasi Mundet and Roberto Rubio. They were also studied using bounded cohomology by Marc Burger, Alessandra Iozzi and Anna Wienhard. These components, together with the Hitchin components were referred as higher Teichmüller components. As Teichmüller space, they all have the property that the mapping class group of S acts freely.

For a long while, it was believed that split and Hermitian groups where the only classes of groups for which higher Teichmüller components existed. The paper under review proves the existence of such type of components also for the family of groups SO(p,q), even when they are neither split or Hermitian. Although this was not originally expected, it was not entirely surprising. Few years earlier, Marta Aparicio in her 2009 PhD thesis studied SO(p,q)-Higgs bundles using the Morse theoretic methods introduced by Hitchin to count components. The original expectation was that components were parametrized by the obvious topological invariants, but it turned out that there were more minima of the Hitchin Morse function than expected, leaving the possibility for the existence of components that are not accounted by the usual topological invariants —a common characteristic of higher Teichmüller spaces.

Another evidence came from the work by Olivier Guichard and Anna Wienhard (2018), where they introduce a notion of positive structure on certain real Lie groups, leading to a notion of positivity for a representation of the fundamental group. They classify the groups admitting positive structures, finding that in addition to split and Hermitian groups, the family SO(p,q) is also there. They conjecture that only the groups having a positive structure admit higher Teichmüller components consisting entirely of positive representations. The work under review, in which there is also a counting of all the topological components of the character variety, strongly supports this conjecture and has paved the way for a general Higgs bundle approach to the characterization of higher Teichmüller components.

"Geometric criteria for overtwistedness"

Authors: Roger Casals, Emmy Murphy and Francisco Presas (ICMAT-CSIC).

Source: Journal of The American Mathematical Society 32 (2019), 563-604.

Date of publication: January 3, 2019

Link

Review:

The history of contact and symplectic topology is a history of war. A war in which you have to keep changing sides and the truth is pushed around all the time. It is an instance of the eternal war between geometry and topology. the geometry side claims that the Contact¹ world follows the rules of the geometry: a rigid world in which the different objects are completely static and the different "contact" animals cannot be classified by just rough shapes. According to their view, you have to define subtle -geometric- invariants, and they will produce many examples of animals lying in the same "topological jail." Moreover, the model geometry that you try to mimic is complex projective geometry: the ideal of a geometer.

In the other side, it lies the topology team, that claims that there is no geometry. the topological jails contain just one animal per jail. there are no surprises: what differential topology puts as necessary condition for the objects to exist is also a sufficient condition. the ideal instance is the world of differential topology.

As in any good war, there has been different alternatives. The 60's and 70's of the XX century were the golden age of the topological (usually called *flexible*) side; they managed to prove that for open manifolds the conditions for existence and classification of contact structures were purely topological. Suddenly, Daniel Bennequin and Mikhael Gromov (respectively in the contact and symplectic area) managed to prove that there was rigidity, that is to say that there were examples of "topological jails" with more than one animal.

The following 90's and 00's witnessed the growth of the *rigidity side* in contact topology. There was an exception, though: in the 3-dimensional case, in 1989 Yakov Eliashberg managed to prove

¹ We will say Contact instead of Contact and Symplectic, both geometries are analogous.



that there was a subclass of contact structures whose existence and classification followed the rules of topology. This flexible class was conformed by the so called *overtwisted structures*. So, the later explosion of the 3-dimensional contact topology has to do with classifying the non-overtwisted (usually called *tight*) contact structures. Moreover, the rigidity team tried to isolate the overtwisted case and to show that it was an exception: the 3-dimensional case was the only particular dimension in which topology played a role.

There were, however, some people looking for the holy grail: the overtwisted class in any dimension. Several attempts were done in the last 20 years: Emmanuel Giroux's definition in terms of negatively stabilized open books; Klaus Niederkrüger's *plastikstufe*, based on generalizing a nice geometric feature of 3D contact structures; the Niederkruger-Presas' *size matters theorems*, hinting a definition which had to do with the radius of normal neighborhoods; the use of a relative version that was first understood: the flexibilitiy of the legendrian knots (loose legendrian embeddings), which provides the elegant conjecture of overtwisted being defined as the class in which the legendrian unknot is loose, etc.

Then, the revolution came: it appeared a general <u>existence</u> result in 5-dimensional contact structures². Its merit was hinting that there was flexibility in all dimensions. In line, it came the <u>general existence and classification result</u>³. That key paper provided a general definition of the overtwisted class. However, the definition was a highly technical partial differential relation very hard to work with, and, in the other hand, there was that long sequence of attempts of definition that were beautiful and much more simple to check in examples.

The article "Geometric criteria for overtwistedness" just claims that all the previous definitions of overtwisted were equivalent to the final one. So, everybody was relieved, their years of efforts were rewarded: their definitions were the real definition. Obviously, the goal of the paper was not just that, it actually uses the advantages of the alternative definitions to show a lot of flexibility statements in contact geometry. In the last year, several results have used this article to push the flexibility side of high dimensional contact topology. After years of defeats, the flexibility team is taking control.

"Approximation theorems for parabolic equations and movement of local hot spots"

Authors: Alberto Enciso (ICMAT-CSIC), María Ángeles García-Ferrero (Heidelberg University) and Daniel Peralta-Salas (ICMAT-CSIC).

Source: Duke Math. J. 168 (2019), 897-939.

Date of publication: 2019

<u>Link</u>

Review:

The theory of global approximation for (linear) elliptic PDE was developed during the period 1950-1965 by Browder, Lax and Malgrange, as a generalization of the classical Runge's theorem in complex analysis. Roughly speaking, it states that given a solution to the PDE defined on a closed set K, there ex-

ists a global solution that approximates it, provided that K satisfies some mild topological assumptions. For parabolic PDE this theory had been developed only for the usual heat equation in Euclidean space and compact sets K. In this paper the global approximation theory for parabolic PDE is developed with the same generality as the elliptic case: parabolic operators with Holder nonconstant coefficients and closed sets Knot necessarily compact.

In the case of the heat equation in Euclidean space, it is shown that in fact the global solution corresponds to a smooth Cauchy datum with compact support. The proofs are technically quite involved and make use of the fundamental solution of the parabolic PDE and several tools from functional analysis, harmonic analysis and parabolic Schauder estimates.

One of the most striking applications of the theory developed in this work is the analysis of the hot spots of the solutions to the heat equation, which is a topic that has attracted an enormous attention in the last years. It is shown that there exist global solutions exhibiting a local hot spot that moves along a prescribed curve for all time, up to a small error that tends to zero as time grows. As a corollary, it is proved that there exist solutions with a hot spot that fills densely the whole space.

Other remarkable application is in the context of isothermic surfaces, i.e. surfaces where the solution is constant (that usually depends on time). It is shown that there exist solutions with isothermic surfaces that change their topology in any prescribed a priori way.

"Lorentzian Einstein metrics with prescribed conformal infinity"

Authors: Alberto Enciso (ICMAT-CSIC) and Niky Kamran.

Source: Journal of Differential Geometry 112 (2019), 505-554.

Date of publication: 2019

<u>Link</u>

Review:

A highly topical subject in the general theory of relativity is the analysis of asymptotically anti-de Sitter (AdS) spacetimes, given their role in the AdS/CFT duality conjectured by Juan Maldacena. Their mathematical interest is focused on the study of the stability or instability of this space when subject to small perturbations, in the context of the Einstein equations.

The existence and uniqueness theorem established by Yvonne Choquet-Bruhat and Robert Geroch is not applied to these spacetimes, which satisfy the Einstein equations with a negative cosmological constant. This is because on the coordinates (known as "wave" coordinates) at which the local existence of solutions can be demonstrated, an AdS-type metric critically diverges: as the inverse square of the distance to the conformal boundary of the spacetime. This singularity is too strong to be included in any standard functional space on which to establish the local existence of solutions. According to Helmut Friedrich, in dimension four, when the Cauchy data (which must satisfy the so-called *constraint equations*) and the contour data fulfil an additional technical condition - which is generally not satisfied - the Einstein equations with hyperboloidal data (that is, of AdS-type) are well posed. In 1998, Edward Witten, on the basis of the classical results obtained by Robin Graham and Jack Lee in Riemannian signature, noted that in general this should actually occur. This is known as the holographic principle for the Einstein equations.

² Casals, Roger; Pancholi, Dishant M.; Presas, Francisco. Almost contact 5-manifolds are contact. *Ann. of Math.* (2) 182 (2015), no. 2, 429–490.

³ Borman, Matthew Strom; Eliashberg, Yakov; Murphy, Emmy Existence and classification of overtwisted contact structures in all dimensions. *Acta Math.* 215 (2015), no. 2, 281–361.

In this paper, Alberto Enciso and Niky Kamran show that the holographic principle is indeed generally valid for the Einstein equations with sufficiently regular *AdS-type* data, without additional hypotheses and in any dimension. Their approach to local existence, which is completely different from the conformal geometry methods employed by Friedrich, is purely analytical. It is based on three principles: the systematic use of estimates with singular weights and derivatives with twist; the development of intrinsically vector function space scales based on a poly-homogeneous regularity, adapted to the AdS geometry at infinity; the construction of a *symbolic peeling calculus*, that is, a partially algebraic procedure that enables the approximate study of the evolution of the asymptotically AdS metrics at infinity, generating only *weak* errors.

"The base change in the Atiyah and the Lück approximation conjectures"

Author: Andrei Jaikin-Zapirain (ICMAT-UAM).

Source: Geometric and Functional Analysis 29 (2019), no. 2, 464-538.

Date of publication: April 2019

<u>Link</u>

Review:

In 1976, Michael Atiyah introduced L^2 -cohomology of manifolds with a free co-compact action of a countable group, like, for example, the universal cover of a compact manifold together with the action of the fundamental group of the manifold by deck transformations. He wanted to extend the Atiyah-Singer index theory of elliptic differential operators to the case of non-compact manifolds. Atiyah defined L^2 -Betti numbers as von Neumann dimensions of the resulting L^2 -cohomology groups. Józef Dodziuk generalized the notion of L^2 -Betti numbers to the context of groups acting on CW -complexes. There is also an algebraic way to introduce L^2 -Betti numbers of a group G:

Let F be a free finitely generated group and let $A \in Mat_{nnm}(\mathbb{C}[F])$ be a matrix over the group ring $\mathbb{C}[F]$. For each quotient G = F/N of F we can define a rank function rk_{G} on matrices over $\mathbb{C}[F]$ such that $rk_{G}(A)$ is the von Neumann rank of the l^{2} -operator

 $\Phi_{G,A}: l^p(G)^n \to l^p(G)^m,$

obtained from the right multiplication by A. The numbers $rk_G(A)$ are called L^2 -Betti numbers of G. For example, in the case where G is finite,

$$rk_{G}(A) = \frac{rk_{c}(A)}{|G|}$$

is the normalized rank of the matrix $\bar{\mathbf{A}} \in Mat_{n \sim m}(\mathbb{C}[G])$ obtained by reducing the coefficients of A modulo the subgroup N.

The two main problems concerning L^2 -Betti numbers are the strong Atiyah and the Lück approximation conjectures. The strong Atiyah conjecture predicts that if the least common multiple lcm(G) of the orders of finite subgroups of G is finite, then $rk_G(A) \in \frac{1}{lcm(G)}\mathbb{Z}$. For example in the case where G is torsion-free, this means that all the numbers $rk_G(A)$ are integers. This claim is a strong version of the Kaplansky and the Malcev conjectures for $\mathbb{C}[G]$. Assuming that G is torsion-free, the Kaplansky conjecture claims that $\mathbb{C}[G]$ is a domain and the Malcev conjecture that $\mathbb{C}[G]$ can be embedded in a division ring. The Lück approximation conjecture is a statement about convergence properties of L^2 -Betti numbers. For example, one of its variations predicts that the map $N \rightarrow rk_{_{F/N}}$ (A) is continuous in the space of marked groups.

In the first result of this paper Andrei Jaikin-Zapirain proves the *sofic Lück approximation conjecture*. In particular, it is shown that the map $N \rightarrow \operatorname{rk}_{F/N}(A)$ is continuous in the space of sofic marked groups. The notion of *sofic groups* was introduced by Mikhail Gromov. Informally, the class of sofic groups consists of groups whose Cayley graph can be approximated by finite graphs. No nonsofic group is known at this moment.

One immediate application of the sofic Lück approximation is that any sofic group satisfies the algebraic eigenvalue property. Observe that if *G* is finite and *A* is a square matrix over *K*[*G*] (where *K* is a subfield of \mathbb{C}), then any eigenvalue λ of $\boldsymbol{\Phi}_{G,A}$ is a root of the characteristic polynomial of $\boldsymbol{\Phi}_{G,A}$, and so, it is algebraic over *K*. It is said that a group *G* satisfies the algebraic eigenvalue property if the eigenvalues of the operator $\boldsymbol{\Phi}_{G,A}$ are algebraic over *K* for any square matrix *A* with coefficients in *K*[*G*]. The algebraic eigenvalue conjecture, formulated by Jósef Dodziuk, Peter Linnell, Varghese Mathai, Thomas Schick, and Stuart Yates in 2003, claims that the algebraic eigenvalue property holds for an arbitrary group *G*.

In the second main result the author applies the sofic Lück approximation and shows that the strong Atiyah conjecture holds for a large class of groups including virtually compact special groups, Artin's braid groups and torsion-free p-adic analytic pro-p groups.

"Average decay for the Fourier transform of measures with applications"

Authors: Renato Lucà (Universität Basel, Suiza) and Keith M. Rogers (ICMAT-CSIC).

Source: J. Eur. Math. Soc. 21 (2019), 465-506.

Date of publication: 2019

Link

Review:

It is well-known that the solution to the Schrödinger equation converges to its initial data in $L^2(\mathbb{R}^n)$ as time tends to zero. Lennart Carleson¹ asked how regular the data should be in order to guarantee that the convergence also holds at almost every point. Considering Sobolev spaces, with *s* derivatives of the data also in $L^2(\mathbb{R}^n)$, the problem consists of identifying the exponents $s \ge 0$ for which the pointwise convergence holds for all the data in the space. In the one-dimensional case (n = 1), Carleson proved that it holds if $s \ge 1/4$ and Björn Dahlberg and Carlos Kenig² proved that there can be divergence if s < 1/4; that is to say, $s \ge 1/4$ is a necessary and sufficient condition when n = 1.

Since then it was believed that the necessary condition of Dahlberg and Kenig should be sufficient in all dimensions³, until Jean Bourgain⁴ proved that *s* has to satisfy $s \ge \frac{1}{2} - \frac{1}{n}$ in order for the pointwise convergence to be guaranteed. This condition is stricter than that of Dahlberg and Kenig in five dimensions or more.

¹ L. Carleson, Lecture Notes in Math. 779 (1980), 5-45.

² B. Dahlberg, C. Kenig, Lecture Notes in Math. 908 (1982), 205-209.

³ T. Tao, Geom. Funct. Anal. 13 (2003), 1359-1384.

⁴ J. Bourgain, Tr. Mat. Inst. Steklova 280 (2013), 53-66.



In this article, due to Renato Lucà and Keith Rogers, Bourgain's result is improved, showing that $s \ge \frac{1}{2} - \frac{1}{n+2}$ is a necessary condition. Their proof combines interference patterns (similar to those appearing in Young's double slit experiment) with ergodic theory, employed in order to show that the constructive interference can appear in a set of positive measure.

In the second part of the article, the rate of decay of the Fourier transform of fractal measures is considered. It is well-known that there may be a direction in which there is no decay, however, after averaging over all directions, there must be at least some decay. Pertti Mattila⁵ considered the problem of identifying $\beta_n(\alpha)$, the maximum rate of decay that is valid for all α -dimensional measures. He proved that $\beta_n(\alpha) = \alpha$ if $\alpha < \frac{n-1}{2}$ and Per Sjölin⁶ proved that $\beta_n(\alpha) = n - 1$ if $\alpha = n$. Bourgain⁷ then made a connection with restriction estimates which helped Thomas Wolff⁸ to identify the precise value of $\beta_2(\alpha)$ in the remaining range, thus solving the problem with n = 2.

In three and more dimensions, the question of Mattila is still open, however, Lucà and Rogers improved the bounds for $\beta_n(\alpha)$. For their upper bound, which limits the the rate of decay, they construct a measure with similar properties to the Schrödinger data that they constructed for Carleson's question. For their lower bound, that shows that the average rate of decay can never be too small, they take advantage of the multilinear restriction estimates proved by Jonathan Bennett, Anthony Carbery and Terence Tao⁹. Finally, they apply their lower bound for $\beta_n(\alpha)$ in order to refine Carleson's question, showing that the pointwise convergence can only fail on a set of small fractal dimension.

"Smooth approximations without critical points of continuous mappings between Banach spaces, and diffeomorphic extractions of sets"

Authors: Daniel Azagra (UCM), Tadeusz Dobrowolski (Pittsburgh State University) and Miguel García Bravo (UAM-ICMAT).

Source: Advances in Mathematics 354 (2019), 106756.

Date of publication: October 1, 2019

<u>Link</u>

Review:

The Morse-Sard theorem asserts that if $f : \mathbb{R}^n \to \mathbb{R}^m$ is sufficiently smooth -meaning that f is of class C^k , with $k \ge \max\{1, n - m + 1\}$ then its set of critical values is of measure zero. A good analogue of the Morse-Sard theorem does not hold in infinite dimensions. Indeed there are \mathbb{C}^∞ functions $f : l_2 \to \mathbb{R}$ whose set of critical values contain intervals. However, in infinite dimensions one can still get the following Morse-Sard type approximation result, which generalizes many of the previous results that one can find in the literature in this context:

Let E, F be separable Hilbert spaces, and assume that E is infinite-dimensional. Then, for every continuous mapping $f: E \to F$ and every continuous function $\varepsilon : E \to \{0, \infty\}$ there exists a C^{∞} mapping $g: E \to F$ such that $\||f(x) - g(x)|\| \le \varepsilon\{x\}$ and $Dg(x): E \to F$ is a surjective linear operator for every $x \in E$.

- 7 J. Bourgain, Israel J. Math. 87 (1994), 93-101.
- 8 T. Wolff, Int. Math. Res. Not. 10 (1999), 547-567.
- 9 J. Bennett, A. Carbery, T. Tao, Acta Math. 196 (2006), 261-302.

In this article, Daniel Azagra, Tadeusz Dobrowolski, Miguel García Bravo prove this result and also provide a version of it, where E can be replaced with a Banach space from a large class -including all the classical spaces with smooth norms, such as c_0 , lp or Lp, 1 , and <math>F can be taken to be any Banach space such that there exists a bounded linear operator from E onto F. In particular, for such E and F, every continuous mapping $f: E \to F$ can be uniformly approximated by smooth open mappings.

Part of the proof provides results of independent interest that improve some known theorems about diffeo-morphic extractions of closed sets from infinite-dimensional Banach spaces or Hilbert manifolds. More precisely, it can be proved that if X a closed subset of E which is locally contained in the graph of a continuous function defined on a subspace of infinite codimension in E and taking values in its orthogonal complement, U is an open subset of E, and G an open cover of E, then there exists a C^{∞} diffeomorphism h of $E \setminus X$ onto $E \setminus (X \setminus U)$ which is the identity on $(E \setminus U) \setminus X$ and is limited by G (meaning that for every $x \in E \setminus X$ we may find a $Gx \in G$ such that both x and h(x) are in Gx). This property ensures that h can be taken to be as close to the identity as we wish.

"The distribution of Galois orbits of points of small height in toric varieties"

Authors: José Ignacio Burgos Gil (ICMAT-CSIC), Patrice Philippon (Institut de Mathematiques de Jussieu – U.M.R. 7586 du CNRS), Juan Rivera-Letelier (University of Rochester) and Martín Sombra (ICREA, UB).

Source: American Journal of Mathematics 141 (2019), 309-381.

Date of publication: April 2019

<u>Link</u>

Review:

Equidistribution results are an important tool in many branches of mathematics. For instance, the equidistribution property the Galois orbits of small points in abelian varieties over number fields was studied by L. Szpiro, E. Ullmo and S. Zhang and led to a proof of the Bogomolov conjecture. This equidistribution property has been widely generalized. In particular, it has been extended to more general varieties and height functions and, with the introduction of Berkovich spaces, to non-Archimedean places. Up to the date of this paper, all these generalizations are restricted to height functions that satisfy a special condition, namely, that the essential minimum of the heights of points is equal to the normalized height of the ambient variety. Many height functions satisfy this special condition, like Néron-Tate heights on Abelian varieties, canonical metrics on toric varieties, and more generally those coming from algebraic dynamical systems. But there are also many height functions of interest that do not satisfy it, like (twisted) Fubini-Study heights on projective spaces and the Faltings height on modular varieties.

Toric varieties form a very nice class of varieties that have a combinatorial description and allow very explicit computations. This paper contains a complete study of the equidistribution property of Galois orbits of small points with respect to toric height functions and the associated Bogomolov property. The authors show that a mild positivity assumption is enough to guarantee equidistribution. This provides a wealth of new height functions for which the equidistribution property holds. Moreover, they give a complete classification of those toric heights for which equidistribution holds, and they

⁵ P. Mattila, Mathematika 34 (1987), 207-228.

⁶ P. Sjölin, Mathematika 40 (1993), 322-330.

use it to prove that the equidistribution property implies the Bogomolov property in the toric context. As a by-product, they give a characterization of those toric heights whose essential minimum is attained. They also provide examples of toric height functions that do not have the Bogomolov property and for which the equidistribution property fails in a myriad of ways.

"Global Existence of Quasi-Stratified Solutions for the Confined IPM Equation"

Authors: Ángel Castro (ICMAT-CSIC), Diego Córdoba (IC-MAT-CSIC) and Daniel Lear (ICMAT-CSIC).

Source: Archive For Rational Mechanics and Analysis 232 (2019), 437-471.

Date of publication: April 2019

Link

Review:

The incompressible porous media (IPM) equation models the movement of incompressible fluids, such as water, through a medium that contains them and hampers their flow, as does sand, for example. The variables used to study this movement are the velocity of the flow, its density and its pressure. The resulting system is composed of three equations that express the principle of mass conservation, the incompressibility condition, and Darcy's law, which states that in a porous medium the velocity of the fluid is proportional to the forces that act upon it. In this paper, the authors consider that the fluid is only subject to the forces of pressure and gravity, so that the three-equation system can be reduced to a single transport equation for the density, the solutions of which determine what the density, velocity and pressure will be, depending on the current density at the time.

The paper addresses the problem of the global regularity of the solutions in a two-dimensional bounded medium. This medium consists of a periodic cell in the horizontal variable, a flat ceiling and a flat floor. It is shown that for PIM there exist regular solutions locally in time; that is, if the initial density is weak, then a weak solution exists during finite time. However, little is known about the global existence of solutions; in other words, it is not known whether it is true that for all the initial density there is a weak solution for all time, or if, on the other hand, an initial weak density exists such that the solution ceases to be weak in finite time. For example, if it can be demonstrated that stationary solutions exist that arise from densities that depend only on the vertical variable, and, considering the case when the fluid lies on all the plane, where Tarek Elgindi, demonstrated that small perturbations of the stationary equation, which takes the form d(y)=-y, yield global solutions that converge in time to the stationary solution.

The result obtained by Ángel Castro, Diego Córdoba and Daniel Lear proves the global existence of solutions for small perturbations of d[y]=-y in a bounded domain. To this end, they construct spaces adapted to the medium and invariant due to the flow of velocity, which include the boundary conditions that the initial density must satisfy in order to yield global solutions. The proof is based on a Galerkin method, energy estimates in these spaces, and on the Duchamel formula, which enables these researchers to take advantage of a dissipation hidden in the linear part of the equation.

"Proof of Taylor's Conjecture on Magnetic Helicity Conservation"

Authors: Daniel Faraco (ICMAT-UAM) and Sauli Lindberg (Helsinki University).

Source: Communications in Mathematical Physics 373 (2019), 707–738.

Date of publication: May 2019

<u>Link</u>

Review:

The so-called magneto hydro-dynamic (MHD) equations govern the behaviour of fluids acted upon by a magnetic field, such as the plasma found in tokamak nuclear reactors, or solar plasma.

In order to analyze these equations, physicists and mathematicians use one of their favourite tools: the study of integral quantities that are either conserved or dissipated over time. However, in different problems concerning hydrodynamics with turbulent regimes, these quantities may not be conserved.

In 1974, John Bryan aylor conjectured that the so-called magnetic helicity, which describes the topological behaviour of magnetic field lines, was practically conserved for small resistivity. In the paper under review, Daniel Faraco and Sauli Lindberg prove this conjecture; that is, they rigorously demonstrate that the magnetic helicity is approximately conserved for limits of Leray Hopf solutions. Furthermore, this conjecture is studied in configurations that are topologically complicated, such as in tokamak reactors, which are not simply connected.

This paper forms part of a larger project whose aim is to understand MHD equations in the framework of the *convex integration* technique and the so-called compensated compactness theorem. Specifically, the analysis of magnetic helicity in these equations is based on the discovery that the time derivative of the helicity is simply the integral of the scalar product of the electric field and the magnetic field.

"T-dual solutions of the Hull-Strominger system on non-Kähler threefolds"

Author: Mario García-Fernández (ICMAT-CSIC).

Source: Journal für die reine und angewandte Mathematik.

Date of publication: June 18, 2019

<u>Link</u>

Review:

The Hull-Strominger system of partial differential equations was proposed by Shing-Tung Yau as an approach to the geometrization of surgeries (transitions and flops) in the passage from algebraic to non-Kähler Calabi-Yau manifolds in complex dimension three. With origins in string theory, these equations relate to a conjectural generalization of the widely studied phenomenon of mirror symmetry, known as (0,2)-mirror symmetry. Unlike in the familiar mirror symmetry for algebraic Calabi-Yau manifolds, the main character of (0,2) mirror symmetry is a compact Calabi-Yau manifold, possibly non-Kähler, equipped with a fiber bundle satisfying suitable topological constraints.

The work by Mario García-Fernández comprises two parts. In the first part he constructs new examples of solutions of the Hull-Strominger system on non-Kähler torus bundles over



K3 surfaces. Upon a choice of natural ansatz, he shows that the existence of solutions reduces to known results about moduli spaces of slope-stable sheaves on a K3 surface, combined with elementary analytical methods. His solutions are comparatively much simpler than the solutions constructed in the same manifolds by J.-X. Fu and S.-T. Yau via the complex Monge-Ampère equation. In the second part he studies qualitative properties of these new solutions in relation to the conjectural (0,2) mirror symmetry. For this, he proves that his solutions appear in pairs related by *topological T-duality*, a geometric version of the T-duality relation between quantum field theories discovered by physicists. His construction provides the first examples of T-dual solutions of the Hull-Strominger system on compact non-Kähler manifolds, and natural candidates for (0,2)-mirror pairs.

"Hypothesis testing in presence of adversaries"

Authors: Jorge González-Ortega (ICMAT-CSIC), David Ríos Insua (AXA-ICMAT), Fabrizio Ruggeri (Istituto di Matematica Applicata e Tecnologie Informatiche, CNR) and Refik Soyer (George Washington University).

Source: The American Statistician (2019).

Date of publication: July 10, 2019

Link

Review:

One of the fundamental problems in statistical inference is hypothesis testing. Although not unaffected by controversy, the problem has been studied in-depth from the perspective of the statistical decision theory, both from a frequentist and a bayesian point of view, as a result of the seminal work carried out by Abraham Wald in 1950. In recent years, there has been a growing interest in hypothesis testing problems, in which hostile adversaries distort the observed data in order to confuse the decision-maker about the relevant hypothesis, with the aim of attaining some objective. These types of problems often occur in fields such as the processing of adversarial signs, adversarial classification and adversarial machine learning, and they have applications in fields like fraud detection, spam identification and autonomous vehicle guidance. However, most of the approaches to these problems employ techniques based on game theory, and involve unrealistic common knowledge hypotheses in the contexts of security described above.

In this paper, Jorge González-Ortega, David Ríos Insua, Fabrizio Ruggeri and Refik Soyer propose an alternative general approach to the problem of adversarial hypothesis testing based on concepts belonging to adversarial risk analysis. They consider an agent (the defender) who must decide which is the most appropriate hypothesis on the basis of observations that may have been distorted by another agent (the attacker). They study the problem from the point of view of the defender, and to do that they formulate a bayesian decision-making problem that requires the prediction of what decision the attacker will make, taking into account the uncertainty regarding the preferences and beliefs of the said attacker; to that end, they employ the adversarial statistical decision theory. Furthermore, they illustrate their results with a specific binary hypothesis testing problem regarding the monitoring of spam. They also discuss several alternative applications.

"Resource Quantification for the No-Programming Theorem"

Authors: Aleksander M. Kubicki (Universitat de València), Carlos Palazuelos (ICMAT-UCM) and David Pérez-García (ICMAT-UCM).

Source: *Physical Review Letters*, 122, 080505 (2019). American Physical Society.

Date of publication: February 28, 2019

<u>Link</u>

Review:

No-go theorems are central in the conceptual foundations of quantum information theory. They serve as guidelines to understand particularities and limits of quantum information. One of such theorems is the so-called no-programming theorem, discovered by M. A. Nielsen and I. L. Chaung two decades ago. The no-programming theorem prohibits the existence of a universal programmable guantum processor, a hypothetical machine able to simulate any quantum operation given the information of the latter encoded in a quantum state. This statement has implications in relation to quantum computation, but also to other tasks of quantum information processing as quantum teleportation or blind computation among others. Nonetheless, it is well known that even when the strict model is not implementable, it is possible to conceive of it in an approximate sense. Unfortunately, the minimal resources necessary for this aim are still not completely understood. Motivated by this lack of knowledge about the no-programming theorem in approximate settings, the authors of this paper investigate quantitative statements of the theorem, delimiting the resources required to build an (approximate) universal programmable quantum processor. The proofs exploit a new connection between guantum channels and embeddings between Banach spaces which allows them to use classical tools from geometric Banach space theory in a clean and simple way.

"The BMO-Dirichlet problem for elliptic systems in the upperhalf space and quantitative characterizations of VMO"

Authors: José María Martell (ICMAT-CSIC), Dorina Mitrea (Missouri University), I. Mitrea (Temple University) and Marius Mitrea (Missouri University).

Source: Analysis & PDE 12 (2019), no. 3, 605-720.

Date of publication: 2019

Link

Review:

E.B. Fabes, R.L. Johnson y U. Neri established in 1976 the well-posedness -that is, there is a unique solution- of the socalled Dirichlet problem for the Laplacian in the upper halfspace \mathbb{R}^{n}_{+} , con $n \geq 2$, and with boundary data in the space of functions with bounded mean oscillation (BMO), when the first order derivatives of the solutions satisfy a Carleson measure estimate. Furthermore, they also obtained a Fatou-type result on which BMO can be described as the collection of nontangential pointwise traces of harmonic functions in the upper half-space whose derivatives satisfy the aforementioned Carleson measure condition. In this recent paper, J.M. Martell, D. Mitrea, I. Mitrea, and M. Mitrea extend these results in several ways. First, they consider elliptic systems with constant complex coefficients, including for instance complex versions of the Lamé system of elasticity. Second, besides working with boundary data in BMO, they treat work with boundary data belonging to its subspace of vanishing mean oscillation functions VMO -where the mean oscillation converges to 0,

uniformly, when the cubes have arbitrarily small size. In such a case, the natural class of solutions is that where the first-order derivatives of the solutions additionally satisfy a vanishing Carleson measure condition (that is, the Carleson measure constant is uniformly small when considered in scales that converge to 0). Furthermore, Fatou-type results are obtained for both BMO and VMO. Namely, BMO and VMO can be identified with the pointwise nontangential traces of the null-solutions whose first-order derivatives satisfy a Carleson measure condition, which is additionally "vanishing" in the VMO case. A remarkable consequence is that smooth functions in BMO are shown to be dense in VMO, fact that improves on Sarason's classical result describing VMO as the closure in BMO of the space of uniformly continuous functions with bounded mean oscillations. Even though this density result in VMO is of a purely real-variable nature, Martell, Mitrea, Mitrea, and Mitrea's argument makes essential use of the PDE-rooted results obtained in the paper. Indeed, any given VMO function is approximated in BMO, by precisely using the solution to the associated Dirichlet problem.



In 2019, the scientific production of ICMAT researchers has exceeded 180 publications.



5. Awards and distinctions

Three new European Research Council projects for ICMAT researchers

European Research Council (ERC) grants are the highest mark of distinction for scientific personnel in Europe. There are three types of funding: Starting, Consolidator and Advanced grants, classified according to the professional experience of the researchers. The ERC Starting Grants are awarded to researchers of any nationality whose eligibility is conditional on their obtaining their doctorate between two and seven years before the publication of the call for applications, and enables them to work in a European research centre. Applications for the ERC Consolidator Grants are open to researchers with between seven and twelve years of experience since the completion of their PhD and who, according to the ERC, "have a scientific track record showing great promise and an excellent research proposal." As regards the ERC Advanced Grants, applications are open to all European scientists who have a track record of significant research achievement in the last ten years. This funding enables them to develop innovative ideas that will play a decisive and progressive role in all fields of knowledge.

At the end of 2019, Alberto Enciso (CSIC-ICMAT) received a Consolidator Grant for studying new properties of partial differential equations and their applications in physics. The project is called "Analysis of geometry-driven phenomena in fluid mechanics, PDE's and spectral theory" and addresses these phenomena through three different approaches. First of all, the formation of singularities in fluid mechanics; secondly, the geometric properties of differential equations, not only in fluid mechanics, with emphasis on fluids in equilibrium, but also in quantum mechanics; and thirdly, in spectral theory. This is the second time that Enciso has been distinguished by the award of an ERC grant. He was awarded an ERC Starting Grant in 2015 for his project "Geometric problems in PDE's with applications to fluid mechanics."

Image: ICMAT



Alberto Enciso

In September of this year, the project "Global existence and computer-assisted proofs of singularities in incompressible fluids, with applications," headed by Javier Gómez-Serrano, was awarded a Starting Grant endowed with 1,485,000 euros over a period of five years. Gómez-Serrano gained his PhD at the ICMAT and was a postdoctoral researcher at the University of Princeton (USA), and although he applied for the ERC project at the ICMAT, he will finally undertake it at the University of Barcelona, where he will occupy a position as a professor. The aim of his project is to obtain methods and develop ideas in order to find both singularities and the global existence of solutions in incompressible fluids with finite energy.



Javier Gómez

Furthermore, the Kari Astala ICMAT Laboratory received an ERC Advanced Grant for the project "Quasiconformal methods in analysis and applications," directed by Kari Astala (University of Aalto, Finland), Daniel Faraco (UAM-ICMAT), Keith Rogers (CSIC-ICMAT) and Xiao Zhong (University of Helsinki, Finland). The first three belong to the Kari Astala Laboratory, which is funded through the ICMAT Severo Ochoa programme and is devoted to harmonic analysis, quasi-conformal geometry and inverse problems.



Kari Astala, Daniel Faraco and Keith Rogers

ICMAT researcher David Pérez García awarded the Banco Sabadell Foundation Prize for Science and Engineering

The Banco Sabadell Foundation has awarded David Pérez García, researcher at the ICMAT and professor at the Complutense University of Madrid (UCM), with the 3rd Banco Sabadell Foundation Prize for Science and Engineering, in which the BIST (Barcelona Institute of Science and Technology) also collaborates. The jury, chaired by the economist Andreu Mas-Colell, awarded the prize in recognition of Pérez García's contribution to quantum information, Banach spaces and operator theory. Pérez García and his team work on the development of a new information theory, combining the ideas of the mathematician Shannon, on how to compress, correct and handle information by means of quantum physics. This prize is one of the most prestigious scientific awards for science in Spain. It is endowed with 50,000 euros and is awarded in recognition of the career achievements of young researchers.



David Pérez

A new European Union Marie Curie project for studying the Fourier transform

ICMAT researcher Javier Ramos has been awarded one of the European Union Marie Curie programme grants to study the so-called restriction of the Fourier transform, the purpose of which is to understand the behaviour of the Fourier transform restricted to null sets. Ramos analyses the particular case of functions that satisfy a series of properties known as L^p . His aim is to "determine for what values of p it is possible to restrict the Fourier transform of functions in L^{p} to certain types of surfaces."





The theses completed at the ICMAT by M^a Ángeles García Ferrero and Carlos Mudarra are awarded two of the 2019 Vicent Caselles Prizes

Carlos Mudarra, a postdoctoral researcher at the ICMAT, and M^a Ángeles García Ferrero, a postdoctoral researcher at Max Planck Institute of Mathematics at Leipzig (Germany), are both former PhD students of the ICMAT. They have each been distinguished with a Vicent Caselles Mathematical Research Prize 2019 from the Royal Spanish Mathematical Society (RSME) and the BBVA Foundation. Awarded to young researchers under 30 years of age who are in the initial stages of their careers, the aim of these prizes is to recognize young mathematicians "whose doctoral work breaks new ground and is influential in mathematical research at an international level, and to encourage them to continue along this path," as stated in the BBVA Foundation citation.

The jury charged with awarding the prizes remarked on García Ferrero, who completed her PhD under the supervision of Alberto Enciso (ICMAT-CSIC), that "her most outstanding results provide a full approximation theorem for solutions to parabolic equations and their application to the study of hot spots and isothermic surfaces." Of Mudarra, a former PhD student of Daniel Azagra (ICMAT-UCM), they state that "in his doctoral thesis he has solved problems regarding the approximation and differentiable extension of convex functions in Banach spaces."



Carlos Mudarra



María Ángeles García Ferrero



6. 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
832 000 €	810 000 €	792 000 €	792 000 €	792 000 €	370 278 €	400 159 €	365 557,64 €	372 200 €

Competitive funding

National Plan

Code	Project	PR	€	Start-final date
EIN2019-103037	"New applications o geometric integration in engineering"	David Martín de Diego	15 500 €	01/06/2019 - 31/12/2021
EIN2019-103354	"The interface between Kähler and non-Kähler geometry"	Mario García-Fernandez	10 000 €	01/6/2019 - 31/05/2020
EUR2019-103821	"Estructuras Topológicas en EDPs"	Daniel Peralta	75 000€	01/10/2019-30/09/2021
PGC2018-097286-B-I00	"Análisis Funcional No Lineal y Geométrico"	Daniel Azagra Rueda	90 508 €	01/01/2019-21/12/2022
ERC2018-092824	"Evolución singular de flujos incompresibles"	Ángel Castro	75 000 €	01/12/2018 -31/05/2020
EQC2018-005104-P	"Adquisición de equipamiento científico-tecnológico"	Ana M. Mancho	102 493,09 €	01/01/2018 -30/06/2020
RTC-2017-6593-7	"SecRating: Plataforma para el cálculo de ratings de ciberseguridad y gestión del ciber riesgo de proveedores"	David Ríos	262 452 €	01/01/2018 -31/12/2019 Prórroga: 31/12/2019 - 30/06/2020
MTM2017-86875-C3-1-R	"Avances en gestión de riesgos para la seguridad"	David Ríos	32 186 €	01/01/2018 - 31/12/2020
MTM2017-89423-P	"Singularities in free surface flows"	Marco Antonio Fontelos	28 677 €	01/01/2018 -31/12/2020
MTM2017-89976-P	"Formación de singularidades en fluidos incompresibles"	Diego Córdoba	51 425 €	01/01/2018 -31/12/2020
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 y 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 Cordoba	51 425 €	01/01/18 -31/12/2020
MTM2017-86875-C3- 1-R	"Avances en gestión de riesgos para la seguridad"	David Rios	32 186 €	01/01/18 -31/12/2020
MTM2017-82690-P	"Invariantes asintóticos de grupos"	Andrei Jaikin	36 300 €	01/01/2018 -31/12/2020
MTM2017-83496-P	"Aritmética y análisis armónico"	Antonio Córdoba y Fernando Chamizo	23 353 €	01/01/2018 -31/12/2020
MTM2017-88385-P	"Métodos matemáticos en información cuántica"	Ignacio Villanueva y Carlos Palazuelos	35 332 €	01/01/2018 -31/12/2020
MTM2017-84098-P	"Fundamentos matemáticos de las tecnologías de la información cuánticas: convexidad, muestreo y algebras de operadores"	Alberto Ibort	58 564 €	01/01/2018 -31/12/2020
MTM2017-82105-P	"Estructuras Algebraicas, Analíticas y o-Minimales STRNAO"	José Francisco Fernando	51 425 €	01/01/2018 -31/12/2021
MTM2016-76072-P	"Análisis geométrico y numérico de sistemas dinámicos y aplicaciones a la física matemática"	David Martin de Diego y Daniel Peralta	65 219 €	30/12/2016 - 29/06/2020
MTM2016-79400-P	"Simetrías en geometría aritmética, algebraica y simpléctica"	José Ignacio Burgos Gil y Francisco Presas	75 141 €	30/12/2016 - 29/06/2020
MTM2016-81048-P	"Geometría de ecuaciones acopladas y espacios de moduli"	Oscar García Prada	45 133 €	30/12/2016 - 29/12/2019
MTM2016-75465-P	"Ecuaciones en derivadas parciales: dinámica asintótica y perturbaciones"	José María Arrieta y Anibal Rodriguez Bernal	52 272 €	30/12/2016 - 29/12/2019
MTM2015-72876-EXP	"Topología Engel"	Francisco Presas Mata	18 150 €	01/05/2017 -30/4/2019
MTM2015-72907-EXP	"Juegos diferenciales estocásticos: rompiendo cincuenta años del paradigma"	Antonio Gómez Corral	30 250 €	01/05/201 - 30/4/2019
SEV-2015-0554	"Programa de Excelencia Severo Ochoa"	Diego Córdoba	4 000 000 €	01/01/2016 -31/12/2020

It is necessary to point out that the great difficulties involved in the management of subsidies and contracts due to the rigidity of CSIC and MINECO procedures. Greater flexibility is required from the CSIC centres for the handling of undertakings such as the Severo Ochoa project.

CSIC (I-Link and I-Coop) Calls

Code	Project	PR	€	Start-final date
CSIC-I-LINK. LINKA20079	"The interplay between geometry, mechan- ics and control in multi-agent systems"	David Martín de Diego	24 000 €	01/01/2019 - 31/12/2020

Regional programmes

Code	Project	PR	€	Start-final date
PEJD-2018-POSTTIC-9375	Grant from the Madrid Government for hiring postdoc. Grant for the incorpora- tion of visiting researchers Investigador: David Gordo	David Ríos	35 000 €	16/03/2019 - 15/03/2020
IND2018/TIC-9901	Grant from the Madrid Government for Industrial Doctorate. Investigador: Bruno Flores	David Ríos	64 000 €	26/02/2019 - 25/02/2022
S2018/TCS-4342	"Quantum Information Technologies Madrid+ (QUITEMAD+-CM) "	Alberto Ibort (UC3M-QC&T) y David Pérez (UCM-MATHQ)	Proyecto: 1 050 060 € Presupuesto ICMAT: 200 000 €	01/01/2019 - 31/12/2022

International Funding

Internationally, the European Union is the main source of funding for the ICMAT. In 2019, the projects in the list below received funding from the EU:

ERC and Marie Skłodowska-Curie projects

Code	Reference	Project	PR	EU Funding	Start-final date
ISOPARAMETRIC	745722	"Geometric and analytic aspects of isoparametric hypersurfaces" Investigador: Miguel Domínguez Vázquez	Alberto Enciso	158 121,60 €	16/04/2017 – 15/01/2019
INVARIANT	335079	"Invariant manifolds in dynamical systems and PDE"	Daniel Peralta	1 260 041,78 €	01/01/2014-30/06/2019
HAPDEGMT	615112	"Harmonic Analysis, Partial Dif- ferential Equations and Geometric Measure Theory"	José María Martell	1 429 790 €	01/01/2014 - 31/12/2019
GEOFLUIDS	633152	"Geometric problems in PDEs with applications to fluid mechanics"	Alberto Enciso	1 256 375 €	01/03/2015-29/02/2020
GAPS	648913	"Spectral gaps in interacting quantum systems"	David Pérez-García	1 462 750 €	01/09/2015 - 31/08/2020
TraX	734557	"Stability and Transitions in Physi- cal Processes"	Florentino Borondo	Total: 526 500 € ICMAT: 63 000 €	01/03/2017 - 28/02/2021
RESTRICTIONAPP	841228	"A multilinear approach to the restriction problem with applica- tions to geometric measure theo- ry, the Schrödinger equation and inverse problems" Investigador: Javier Ramos	Keith Rogers	172 932,48 €	01/08/19 – 02/10/2021
NONFLU	788250	"Non-local dynamics in incom- pressible fluids"	Diego Córdoba	1 779 369 €	01/09/2018-31/08/2023
QUAMAP	834728	"Quasiconformal Methods in Anal- ysis and Applications"	Kari Astala. ICMAT members: Daniel Faraco and Keith Rogers	Total: 2 280 350 € ICMAT: 771 850 €	01/09/2019-31/08/2024



H2020 Industrial Leadership Pillar

Code	Reference	Project	PR	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

Code	Reference	Project	PR	EU Funding	Start-final date
CYBECO	740920	"Supporting Cyberinsurance from a Behavioural Choice Perspective"	David Ríos	Financiación: 1 983 510,00 € Presupuesto ICMAT: 251 250,00 €	01/05/2017 – 30/04/2019
Trustonomy	815003	"Building Acceptance and Trust in Autonomous Mobility"	David Ríos	Financiación: 3 920 000 € Presupuesto ICMAT: 206 500 €	01/05/2019 – 30/04/2022

Other projects

National Science Foundation (NSF)

Code	Project	PR	Budget	Start-final date
DMS-1901290	"Operator Algebras, Groups, and Applications to Quantum Information"	David Kerr (Texas A&M) and Fernando Lledó	36 000 \$	21/12/2018 - 29/02/2020

Private funding

Title	Reference	Project	PR	€	Start-final date
Axa Permanent Chair	01AXACT01	"Análisis de Riesgo Adversario"	David Ríos	1 100 000 € (147 000 €por año)	01/09/2014 -31/08/2022
Beca Iberoamérica Santander Investigación 2018	Co4Drones.	"Planificación de trayectorias interpoladoras y localización de agentes mediante sensores de distancia en el diseño de controles para la formación de múltiple rotorcrafts (drones)"	Leonardo Colombo	4790 €	01/01/2019 -31/12/2020

Moreover, the ICMAT received funding for the organization of congresses and school from the following institutions:

USA Office of Naval Research (ONR)

Code	Project	PR	€	Start-final date
N00014-17-1-3003	"Dynamical systems and geophysical flows: new perspectives and applications"	Ana María Mancho	70 000 €	30/09/2017 - 30/09/2019

7. Severo Ochoa Programme

The second ICMAT Severo Ochoa programme came to an end in 2019. As in previous years, much of the budget was devoted to the appointment of personnel: management technicians and pre- and post-doc researchers who have contributed to the programme of excellence at the ICMAT. Likewise, this funding has served to cover service commissions formed by research personnel, and has also provided seven collaboration grants for students on master courses in mathematical research in order to cover their tuition fees as well as financial support of 1,000 euros per month during their training. Funding has also been provided to final-year graduate students for the introduction to research scheme, with the aim of enabling them to join the JAE School and to undertake research stays with ICMAT members.

Activities at the ICMAT Laboratories have also received funding, mainly to cover members' travel expenses and also for visitors at the laboratories, as well as for specific activities conducted in each programme.

In addition, the following scientific activities have also been funded:

- "III International Workshop on Information Geometry, Quantum Mechanics and Applications"
- "II BYMAT Conference: Bringing Young Mathematicians Together"
- "Workshop on Banach spaces and Banach lattices"
- Course: "Growth and relations of graded rings"
- "Advanced Resolution Techniques for Equations in Mathematical Physics"
- "Summer school on fluid mechanics"
- "13th International ICMAT Summer School on Geometry Mechanics and Control"
- "Homogenization, Spectral problems and other topics in PDE's"
- "Escuela JAE"
- "Advanced school on representations of pro•p groups"
- "11th International Workshop on Bayesian Inferencia in Stochastic Process"
- "Celebración del 150 aniversario de la tabla periódica"
- "Groups in Madrid"

Worthy of mention is funding for the thematic trimesters devoted to various subjects of interest in current research. Throughout 2019, these have been:

- "Operator Algebras, Groups and Applications to Quantum Information"
- "Current trends in geometric methods in natural sciences"
- "Research term on Quantum Information Theory"

Among these activities, expenses for the travel, food and coffee breaks of some of the participants have also been met.

Funding has also been devoted to cover the different seminars and symposia held at the ICMAT, to which must be added expenses arising from the visitors scheme, which in 2019 enabled 15 researchers to carry out stays at the ICMAT; expenses incurred by outreach and communication activities at the centre; expenses for the Gender Plan, and those for inventory material (mainly informatic) and fungibles; training expenses for members of the centre and representation expenditure.

8. Scientific activities

CONGRESSES, SCHOOLS AND THEMATIC RESEARCH PROGRAMS

A total of 36 conferences, schools and courses in various disciplines were held at the ICMAT in 2019, such as in geometry, group theory, harmonic analysis, Banach spaces and fluid mechanics. Three thematic research programs were also held; two in the field of quantum information and one in geometry. All these activities enabled the Institute to welcome international specialists in different fields.

Added to this was the day-to-day activity at the centre, consisting of seminars organized on a weekly basis and colloquies in collaboration with the UAM and the UCM. Moreover, 17 doctoral theses were read, and the JAE School was also held for final-year master graduate students wishing to be introduced to the world of mathematical research.

Altogether, some 270 scientific activities and events took place at the Institute, which is a reflection of the intense activity undertaken at the ICMAT, placing it as one of the epicentres of international research in mathematics.

Thematic research programmes, congresses, schools and courses

Below, all the schools, congresses and thematic research programmes held at ICMAT throughout 2019 are listed:

Thematic research programmes

• "Operator Algebras, Groups and Applications to Quantum Information"

March 11 – June 29

Organising committee: Cécilia Lancien (Université de Toulouse), Fernando Lledó (ICMAT-UC3M), Diego Martínez (ICMAT-UC3M), Carlos Palazuelos (ICMAT-UCM) and Julio de Vicente (UC3M).

Web

In total, more than 140 specialists in the areas of mathematical physics, noncommutative algebra, dynamical systems, group theory, harmonic analysis, topology and quantum theory from 15 different countries came to the Institute. Among these we may mention Joachim Cuntz (WWU-Münster), one of the outstanding figures in the area of operator algebras, who gave the inaugural talk at the first colloquy. The main objective was to foster interaction between all these fields, paying special attention to their applications to quantum information. The following activities were organized within the framework of this particular thematic program:

- <u>School I</u> (March 11 15)
- Workshop | (March 18 22)
- <u>School II</u> (May 6 10)
- Workshop II (May 13 17)
- International Conference (June 17 21)
- <u>Visitor program and running seminar</u> (March 11 June 29)



"Current trends in Geometric Methods in Natural Sciences"

September 2 – December 20

Organising committee: María Barbero (UPM), Leonardo Colombo (ICMAT-CSIC), Alberto Enciso (ICMAT-CSIC), David Martín de Diego (ICMAT-CSIC), Francisco Presas (ICMAT-CSIC), Cristina Sardón (UPM) and Piergiulio Tempesta (ICMAT-CSIC).

<u>Web</u>

The ICMAT can count on a significant number of specialists in geometric methods with applications to quantum mechanics, relativity and cosmology, field theory, thermodynamics, classical and fluid mechanics and the numerical simulation of physical systems, among other fields. They came together over several months to organize this thematic programme that included the following activities:

- "XXVIII Fall Workshop on Geometry and Physics" (September 2 6)
- "GESTA School" (10 13 de diciembre)
- "Workshop on Geometric Methods in Symplectic Topology" (December 16 – 20)



• "Quantum Information Theory," Lab Ignacio Cirac

September 9 – October 18

Organising committee: José L. F. Barbón (IFT-CSIC), Juan José García-Ripoll (IFF-CSIC), Alberto Ibort Latre (IC-MAT-UC3M), Esperanza López (IFT-CSIC), Carlos Palazuelos Cabezón (ICMAT-UCM), David Pérez García (ICMAT-UCM), Enrique Rico (UPV), Germán Sierra Rodero (IFT-CSIC) and Enrique Solano (UPV). The ICMAT Ignacio Cirac Laboratory, in collaboration with the Institute of Theoretical Physics, organized this thematic program devoted to the theory of quantum information. The event provided a platform for meetings and discussions in which research personnel were able to share new ideas and advances in the field, and where recent arrivals could learn about the goals, techniques and challenges arising from quantum technologies. The program was divided into the following activities:

- Workshop: <u>"Entangle This IV: Chaos, Order and Qubits"</u> (September 9 – 13)
- Focus weeks:
 - Focus week on Tensor Networks (September 16 20)
 - Focus week on Foundations of Quantum Information (September 23 – 27)
 - Focus week on Quantum Cryptography (September 30 October 4)
 - o Focus week on Quantum Computing (October 7 11)
- Conference: <u>"Quantum Simulation and Computation</u> <u>(QSC2019)"</u> (October 14 – 18)



Congresses

• "Homogenization, Spectral Problems and Other Topics in PDE's"

May 6 - 7

Organising committee: José M. Arrieta (ICMAT-UCM), Rafael Orive (ICMAT-UAM) and María Eugenia Pérez (Universidad de Cantabria).

<u>Web</u>

This conference was a meeting place between young researchers and experts in the area of partial differential equations and their applications to spectral and homogenization, among other fields.

• "Second BYMAT Conference – Bringing Young Mathematicians Together"

May 20 – 24

Organising committee: Alberto Redondo (ICMAT-CSIC), Ángela Capel (ICMAT-UAM), Blanca Fernández Besoy (UCM), Jesús Ocáriz (ICMAT-UAM), Makrina Agaoglou (ICMAT-CSIC), Patricia Contreras Tejada (ICMAT-CSIC), Roi Naveiro (ICMAT-CSIC) and Teresa Luque (UCM).

<u>Web</u>

This conference constituted the second meeting of the BYMAT network, which supports young researchers in their professional development both within and outside academia, and also strengthens the connection between mathematics and contemporary society. It consisted of seven plenary addresses as well as short talks, poster sessions, chats and workshops dealing with career opportunities and communication and mathematical outreach.



"11th International Workshop on Bayesian Inference in Stochastic Processes"

June 12 – 14

Organising committee: David Ríos (ICMAT-CSIC), Marta Sanz (ICMAT-CSIC), Alberto Redondo (ICMAT-CSIC), Víctor Gallego (ICMAT-CSIC), Ernesto Nungesser (ICMAT-CSIC), Roi Naveiro (ICMAT-CSIC) and Jorge González Ortega (ICMAT-CSIC).

Web

• "Donaldson-Hitchin Lab Summer Workshop"

July 15 – 16

Organising committee: Laboratorio Donaldson-Hitchin ICMAT

More information

"Workshop on Banach Spaces and Banach Lattices"

September 9 – 13

Organising committee: Antonio Avilés (Universidad de Murcia), Héctor Jardón (Universidad de Oviedo) and Pedro Tradacete (ICMAT-CSIC).

<u>Web</u>

The conference brought together specialists from all over the world in Banach spaces, vector spaces endowed with a norm that enables vectors to be measured (and thus distances between elements of the space). It consisted of four mini-courses and six plenary addresses, as well as short talks and daily poster sessions.

• Kari Astala Lab: "Agapi Days"



- Organising committee: Kari Astala ICMAT Laboratory
 - o "Agapi Days IV" (April 25)
 - o "Agapi Days V" (May 30)
 - o "Agapi Days VI" (September 26 27)

<u>Web</u>

Activities organised in the framework of the AGAPI research group, linked to the Kari Astala ICMAT Laboratory.

• "Groups in Madrid"

November 28 – 29

Organising committee: Yago Antolín (ICMAT-UCM), Javier Aramayona (ICMAT-UAM), Andrei Jaikin (ICMAT-UAM) and Carolina Vallejo (ICMAT-UAM).

<u>Web</u>

Fifth edition of this anual congress about recent developments in group theory.



• "Software Carpentry Workshop"

November 28 - 29 and December 4

Organising committee: CFTMAT

<u>Web</u>

The purpose of the Software Carpentry workshop was to help researchers complete their work more easily and in less time by teaching them basic computer skills for tackling research tasks. This practical workshop covered basic tools and concepts including programme design, version control, data administration and concepts and task automation. The participants were encouraged to help each other and to apply what they were learning to their own research problems.

Schools

• "JAE School of Mathematics 2019"

June 10 – 22

Organising committee: Yago Antolín (ICMAT-UCM) and Mario García (ICMAT-UAM).

<u>Web</u>

The JAE School of Mathematics is organized by the ICMAT and takes place every summer. It is aimed at master and final year degree students who are interested in learning about mathe-



matical research and its applications. Over the course of two weeks, the students are introduced to fields of mathematics that are not usually included in university courses. The goal of the School is to encourage students to take up a research career and to interact with the top rank mathematicians who impart the JAE courses.

"Summer School on Fluids Mechanics at the ICMAT"

June 24 – 28

Organising committee: Ángel Castro (ICMAT-CSIC) and Diego Córdoba (ICMAT-CSIC).

<u>Web</u>

The first summer school on fluid mechanics brought together 50 students interested in this field with international experts. Six courses were given, each lasting three hours, in which subjects of great interest in current research were introduced, such as the study of weak solutions for the Navier-Stokes equations, the singularity and symmetry in two-dimensional incompressible fluid equations, and the loss of regularity in the solutions to these equations, among others.

• "Advanced School on Representations of Pro-p Groups"

July 8 – 12

Organising committee: Yago Antolín (ICMAT-UCM), Andrei Jaikin (ICMAT-UAM) and Diego López Álvarez (ICMAT-CSIC). Web

"13th International ICMAT Summer School on Geometry, Mechanics and Control"

July 8 – 10

Organising committee: María Barbero Liñán (UPM), David Iglesias Ponte (Universidad de La Laguna), David Martín de Diego (ICMAT-CSIC) and Edith Padrón (Universidad de La Laguna).

Web

Courses

- "Small Cancellation Theory"
 - January 28 31
 - Organising committee: ICMAT-UAM
 - More information
- "Sistemas complejos: Modelos y análisis de (big) data"
- February 20
- Organising committee: Florentino Borondo (ICMAT-UAM)
- More information
- "An Introduction to Class Field Theory: The Artin Reciprocity Law"
 - March 19, 26 and 27
- Organising committee: ICMAT-UAM
- More information
- "Growth and Relations of Graded Rings"
 - May 6 10
 - Organising committee: Andrei Jaikin (ICMAT-UAM)

- <u>Web</u>

- "Series of lectures on Higgs Bundles and Higher Teichmüller Spaces," by Oscar García Prada
 - July 2, 4 and 5
- Organising committee: Oscar Gacía Prada (ICMAT-CSIC)
- More information
- "Oportunidades de financiación europea en matemáticas"
 - September 30
 - Organising committee: Red Estratégica en Matemáticas (REM) and ICMAT.
- More information
- "Hamiltonian Framework of an Ideal Hydrodynamics: Casimirs and Vortex Structures"
 - October 2 3
 - Organising committee: Thematic research programme "Current Trends in Geometric Methods in Natural Sciences."
- More information
- "Hyperbolic and Dispersive Free Boundary Problems"
 - November 4 7
 - Organising committee: ICMAT
 - More information

ICMAT LABORATORIES

Charles Fefferman Laboratory



Activities organised in 2019:

- "Working Seminar on PDE's and Fluid Mechanics," ICMAT.
- "Summer school on fluids mechanics," ICMAT.
- Workshop: "PDE's in fluids mechanics," Castro Urdiales (CIEM).
- Seminar: "Global in time and mixing solutions for the Incompressible Porous. Media equation (IPM)," Diego Córdoba. Princeton University.

Papers published:

- "Global solutions for the generalized SQG patch equation," D. Córdoba, J. Gómez-Serrano & A. D. Ionescu. Arch. Ration. Mech. Anal. 233 (2019) no3. 1211-1251.
- "Splash singularities for the free boundary Navier-Stokes equations," A. Castro, C. Fefferman, D. Córdoba, F. Gancedo, J. Gómez-Serrano, *Ann. PDE* 5 (2019), no.1, Art.12, 117pp.
- "Global existence of quasi-stratified solutions for the confined IPM equation," A. Castro, D. Córdoba & D. Lear. Arch. Ration. Mech. Anal, 232 (2019), no.1, 437-471.
- "Uniformly rotating smooth solutions for the incompressible 2D Euler equations," A. Castro. D. Córdoba & J. Gómez-Serrano. Arch. Ration. Mech. Anal., 231(2019), no.2, 719-785.
- "Self-intersecting interfaces for stationary solutions of the two-fluid Euler equations," D. Córdoba, A. Enciso & N. Grubic. Preprint arxiv:1906.02612.

Trips:

- Diego Córdoba (ICMAT-CSIC), Princeton University. March.
- Conference: "Fluid-Squeezing singularities," workshop: "Fluid turbulence and Singularities of the Euler/ Navier Stokes equations." Harvard University. March.
- Javier Gómez Serrano (Princeton University), ICMAT. May, June and July.
- Javier Gómez Serrano (Princeton University), ICMAT. December.

Kari Astala Laboratory



Activities organised in 2019.

- "Agapi Days IV" (April 25)
- "Agapi Days V" (May 30)
- "Agapi Days VI" (September 26 27)

Papers published:

- "Uniqueness of normalized homeomorphic solutions to nonlinear Beltrami equations," K.Astala, A.Clop, D. Faraco J. Jääskelainen and L. Szekelyhidi. <u>Preprint</u>.
- "Proof of Taylor's Conjecture on Magnetic Helicity Conservation," D. Faraco and S. Lindberg. *Communications in Mathematical Physics*, volume 373, pages 707–738 (2020).
- "Bounded solutions of ideal MHD with compact support in space-time," D. Faraco, S. Lindberg and L. Székelyhidi Jr. <u>Preprint</u>.

Trips:

- Daniel Faraco (ICMAT-UAM), Aalto University. June 15 September 15.
- Kari Astala (Aalto University), ICMAT. March 1 May 30.

Contracts:

- Lauri Hitruhin. Postdoctoral contract. September 1 December 31, 2019.
- Diego Alonso Orán. Postdoctoral contract. May October, 2019.

Distinctions:

• ERC Advanced Grant, with three members of this laboratory.



ICMAT LABORATORIES

Ignacio Cirac Laboratory



Activities organised in 2019:

- Thematic research programme: "<u>Operator Algebras, Groups</u> and <u>Applications to Quantum Information</u>."
- Thematic research programme: "Quantum Information Theory."

Papers published:

 "Mathematical open problems in projected entangled pair states," J.I. Cirac, J. GarreRubio and D. PérezGarcía, *Revista Matemática Complutense*, 32 (3), 579599 (2019).

Trips:

- Ignacio Cirac (Max Planck Institute of Quantum Optics) and several members of his group –Norbert Schuch, Maricarmen Bañuls, Christoph Sünderhauf, todos del Max Planck Institute of Quantum Optics–, were participants in the thematic research programme "Quantum Information Theory," held at the ICMAT.
- Andras Molnar (Max Planck Institute of Quantum Optics), IC-MAT. May.

Contracts:

• Andras Molnar. Postdoctoral contract. September 2019.

Laboratorio Donaldson-Hitchin



Activities organised in 2019:

- Minicourse: "Higgs bundles and higher Teichmueller spaces," given by Oscar García-Prada at the ICMAT.
- "Donaldson-Hitchin Lab Summer Workshop," ICMAT.
- Geometry seminar, given by Nigel Hitchin (University of Oxford).
- Invited conference. Oscar García-Prada, workshop: "<u>Novel</u> <u>Vistas on Vortices</u>" (Stony Brook).
- Invited conference. Oscar García-Prada, congress: "<u>Holo-morphic differentials in Mathematics and Physics</u>" (Berkeley University).

Trips:

- Oscar Garcia-Prada, Simons Center for Geometry, Physics (Stony Brook) and Mathematical Sciences Researc Institute (Berkeley University). October 23 – November 23.
- Oscar García-Prada, University of Oxford. July 27 August 10.
- Nigel Hitchin (University of Oxford), ICMAT. July 14 20.
- Oscar García Prada, Simons Center for Geometry and Physics (Stony Brook). February 3 – 10.
- Oscar García-Prada, Center for Geometry and Physics (Stony Brook). March 17 31.
- Oscar García-Prada, University of Oxford. February 22 28.
- Emilio Franco Gomez (Universidad de Lisboa, Portugal), ICMAT. February 22 May 31 and July 15 19.
- Claude LeBrun (Universidad de Stony Brook, EEUU), ICMAT. March 4 – 8 and May 27 – June 1.
- David Fernández Álvarez (Bielefeld University), February 18

 March 12.
- Ignasi Mundet i Riera (Universidad de Barcelona). March 12 - 13.
- Jock MacOrist (Surrey University). March 25 April 19 and October 21 November 29.
- Suratno Basu (CMI, Chennai, India). May 5 22 and August 10 31.
- Peter Gothen (Oporto University). March 12 13 and July 8 12.
- Brian Collier (Maryland University). July 5 12.
- Steven Bradlow (Illinois at Urbana-Champaign University). July 5 - 12.
- Andre Oliveira (Oporto University). July 7 14.
- Jacques Hurtubise (McGill, Montreal). July 14 21.
- Dietmar Salamon (ETH Zurich). October 9 20.
- Challenger Mishra (University of Oxford). December 9 13.

COLLOQUIA

The programme of joint colloquia with the UAM and UCM was continued throughout 2019, as well as the special colloquia organized by the ICMAT.

UAM-ICMAT Colloquium

Co-ordinators: Yago Antolín (ICMAT-UCM), Javier Aramayona (ICMAT-UAM) and Tomás Luis Gómez de Quiroga (ICMAT-CSIC).

Colloquia:

- "<u>On Some Results and Conjectures in the Theory of Auto-</u> morphic Forms," Pilar Bayer (Universidad de Barcelona). April 12.
- "<u>Brownian Geometry on the Sphere,</u>" Jean-François Le Gall (Université Paris-Sud). May 10.
- "<u>Conformal Geometry on 4-manifolds,</u>" Sun-Yung Alice Chang (Princeton University). June 7.
- "<u>Geometric Valuation Theory</u>," Monika Ludwig (Technische Universit at Wien). November 8.
- "<u>Finite Shadows of Infinite Groups</u>," Martin Bridson (University of Oxford). November 29.



ICMAT-UCM Colloquium

Co-ordinators: Piergiulio Tempesta (ICMAT-UCM) and David Martín de Diego (ICMAT-CSIC).

Coloquia

- "<u>Fractalization and Quantization in Dispersive Systems</u>," Peter J. Olver (School of Mathematics, University of Minnesota). June 25.
- "<u>The Inverse Problema for Lagrangians,</u>" Geoff Prince (La Trobe University, Melbourne). July 19.
- "<u>Geometric Control and Sub-riemannian Problems,</u>" Fátima Silva Leite (University of Coimbra). November 28.





Colloquium ICMAT-UCM

GEOMETRIC CONTROL AND SUB-RIEMANNIAN PROBLEMS

SPEAKER: Fátima Silva Leite (University of Coimbra)

DATE: Thursday, November 28th 2019 - 12:00

VENUE: Aula Naranja, ICMAT

ABSTRACT: The first part of this talk introduces the basic concepts of geometric control theory, namely controllability and optimal control. A control system is a family of dynamical systems parameterized by the controls, evolving on a manifold [the state space]. Controllability is related to the ability to reach a state from any other state, using the available controls. Optimal control deals with the possibility to do it in the best possible way. These concepts will be illustrated with simple examples.

The second part of the talk focus on recent results about sub-Riemannian structures on Lie groups and homogeneous spaces, using tools from optimal control, with particular emphasis on sub-Riemannian geodesics.





Fátima Silva gave a Colloquium ICMAT-UCM in November.



SPECIAL Colloquium

Coordinator: ICMAT

Coloquia:

- Inaugural Colloquium: "Operator Algebras, Groups and Applications to Quantum Information Thematic Research Program," Joachim Cuntz (WWU Münster). March 13.
- "<u>Superintegrable Systems</u>," Nicolai Reshetikhin (University of California, Berkeley). October 23.
- "Enhanced Symmetry in the Semiclassical Category and Characters of Loop Groups," Jonathan Weitsman (University of Northeastern). October 28.



SPECIAL COLLOQUIUM

ENHANCED SYMMETRY IN THE SEMICLASSICAL CATEGORY AND CHARACTERS OF LOOP GROUPS



VENUE: Aula Naranja, ICMAT

ABSTRACT: We consider a version of Weinstein's symplectic category, adapted for the case of quasi-Hamiltonian G-spaces. We show that semiclassical quantization in this setting produces the Kac character formula, in analogy with the construction of the Weyl character formula by Guillemin and Sternberg in the symplectic setting. We show that this construction gives a natural action of the modular group on the Kac characters, which we conjecture agrees with Kac's SL(2,2) action. We conjecture also that a similar construction should give rise to enhanced symmetries—that is, symmetries of the quantization that do not arise from symmetries of the underlying classical system—also in some other examples. [Joint with Peter Crooks].



SEMINARS

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

- Analysis and applications seminar. Coordinators: José Conde (ICMAT - UAM) and José María Martell (ICMAT – CSIC).
- Applied mathematics seminar. Coordinators: Jezabel Curbelo (ICMAT UAM) & Carlos Escudero (UNED).
- Geometry seminar. Coordinator: Mario García Fernández (ICMAT - UAM).
- Geometric mechanics and control seminar. Coordinator: Leonardo Colombo (ICMAT - CSIC).
- Number theory seminar. Coordinator: Daniel Macías (ICMAT-UAM).
- Group theory seminar. Coordinator: Yago Antolín (ICMAT–UCM).
- Junior Seminar. Coordinators: Ángela Capel Cuevas (ICMAT-UCM) & Nikita Simonov (UAM).
- DataLab Seminar. Coordinators: Roi Naveiro (ICMAT-CSIC) and Marta Sanz (ICMAT-CSIC).
- Communtative Algebra-Algebraic and Aritmetic Geometry seminar. Coordinator: Ana Bravo (ICMAT-UAM).
- PDE's and Fluid Mechanics seminar. Coordinators: Ángel Castro (ICMAT-CSIC) and Diego Córdoba (ICMAT-CSIC).
- Q-Math Seminar. Coordinator: Juan Manuel Pérez Pardo (ICMAT-UC3M).

A total of 200 seminars were held in 2019, distributed in the following fields:

- a) Analysis and applications: 31
- b) Applied mathematics: 16
- c) Commutative algebra, algebraic and arithmetic geometry: 5
- d) DataLab: 12
- e) Geometry: 35
- f) Geometric mechanics and control: 10
- g) Group theory: 29
- h) Junior: 15
- i) Number theory: 13
- j) PDE's and fluid mechanics: 8
- k) Q-Math: 11
- l) Others: 15

9. Theses

17 researchers completed their PhD theses at the ICMAT in 2019. The titles, authors and supervisors of which are listed below:

- On the Method of Bukhgeim for Two-dimensional Inverse <u>Problems</u>, Jorge Tejero Tabernero (ICMAT-CSIC). Supervisors: Daniel Faraco (ICMAT-UAM) and Keith M. Rogers (ICMAT-CSIC). Date: February 22.
- <u>Análisis armónico en dominios irregulares</u>, Juan Cavero (ICMAT-CSIC). Supervisor: José María Martell (ICMAT-CSIC). Date: March 24.
- <u>Stability Near Hydrostatic Equilibrium in Fluid Mechan-</u> ics, Daniel Lear (ICMAT-CSIC). Supervisors: Diego Córdoba (ICMAT-CSIC) and Ángel Castro (ICMAT-CSIC). Date: March 29.
- 4. <u>Sharp Estimates for Linear and Nonlinear Wave Equations</u> via the Penrose Transform, Giuseppe Negro. Supervisors: Thomas Duyckaerts (Université Paris 13) and Keith Rogers (ICMAT-CSIC). Date: April 11.
- <u>Regularity Results for Some Models in Geophysical Fluid</u> <u>Dynamics</u>, Diego Alonso Orán (ICMAT-CSIC). Supervisor: Antonio Córdoba (ICMAT-UAM). Date: April 12.
- Exact Results on Quantum Many-body Systems in One Dimension, José Antonio Carrasco Blanco (ICMAT-UCM). Supervisors: Federico Finkel Morgenstern (UCM), Artemio González López (UCM) and Piergiulio Tempesta (ICMAT-UCM). Date: June 20.
- <u>Discrete Mechanics for Forced and Constrained Systems</u>, Rodrigo T. Sato (ICMAT-CSIC). Supervisor: David Martín de Diego (ICMAT-UAM). Date: July 10.
- Weighted inequalities in Fluid Mechanics and General Relativity: Carleman estimates and cusped traveling waves, Bruno Alexis Vergara Biggio (ICMAT-CSIC). Supervisor: Alberto Enciso (ICMAT-UAM). Date: July 16.
- Moderately Discontinuous Algebraic Topology for Metric Subanalytic Germs, Sonja Heinze (ICMAT-UCM). Directores/ as: Javier Fernández de Bobadilla (BCAM) and María Pe Pereira (UCM). Date: October 31.
- <u>Invariants of Singularities, Generating Sequences and Toroidal Structures</u>, Miguel Robredo Buces (ICMAT-CSIC). Supervisor: Pedro D. González Pérez (UCM). Date: October 31.
- Symmetries in Topological Tensor Network States: Classification, Construction and Detection, José Garre Rubio (ICMAT-UCM). Supervisors: David Pérez García (ICMAT-UCM) and Sofyan Iblisdir (UCM). Date: November 14.
- Material Geometry, Víctor Manuel Jiménez Morales (ICMAT-CSIC). Supervisors: Manuel de León (ICMAT-CSIC) and Marcelo Epstein (University of Calgary). Date: November 15.
- Singular Integrals and Boundary Value Problems for Elliptic Systems, Juan José Marín García (ICMAT-CSIC). Supervisors: José María Martell (ICMAT-CSIC) and Marius Mitrea (University of Missouri). Date: November 15.
- Orderability in Contact Manifolds, José Luis Pérez García (ICMAT-CSIC). Supervisor: Francisco Presas (ICMAT-CSIC). Date: November 29.
- 15. <u>Quantum Logarithmic Sobolev Inequalities for Quantum Ma-</u> ny-body Systems: An Approach via Quasi-factorization of the

<u>Relative Entropy</u>, Ángela Capel Cuevas (ICMAT-UAM). Supervisors: David Pérez García (ICMAT-UCM) and Angelo Lucia (California Institute of Technology). Date: December 16.

- 16. <u>Reaction-diffusion Processes and their Interdisciplinary</u> <u>Applications</u>, Álvaro Isidro Correales (ICMAT-CSIC). Supervisor: Carlos Escudero Liébana (UNED). Date: December 16.
- Manifestaciones cuánticas del caos en el sistema molecular kcn, Horacio Párraga (UPM). Supervisors: Florentino Borondo (ICMAT-UAM) and Francisco Javier Arranz (UPM). Date: December 20.



Víctor Jiménez (centre) with his thesis advisors and committee.



Juan José Marín (centre) with his thesis advisor and committee.



Ángela Capel with one of her thesis advisor (left) and committee.



10.Institutional Networks

Strategic Network of mathematics (REM)



In 2016, the <u>Red Estratégica en Matemáticas</u> (REM – Strategic Network in Mathematics) was configured as a network to include all the important nodes of mathematical research and knowledge transfer in Spain. The REM is a project funded by the State Research Agency, which consists of:

- CRM/BGSMATH (Centre de Recerca Matemàtica/ Barcelona Graduate School in Mathematics)
- BCAM (Basque Center for Applied Mathematics)
- ICMAT (Instituto de Ciencias Matemáticas)
- REDIUM (Red de Institutos Universitarios de Matemáticas)
- math-in (Red Española Matemática-Industria)
- Centros Públicos de Educación Superior
- Coordinator: IMUS (Instituto de Matemáticas de la Universidad de Sevilla)

On the basis of the strategic nature of mathematics as recognized in the R+D+i National Plan, its objectives consist of improving the national and international strategic positioning of Spanish mathematics as well as its scientific and economic impact. Six strategic actions are adopted within this framework:

- Action 1: Study of the results obtained in mathematical research during the last decade.
- Action 2: Support for the measures of transfer of mathematical technology conducted across the board.
- Action 3: Diffusion of the activities and results of mathematical research in Spain.
- Action 4: Strengthen the presence of Spanish mathematics in the world.
- Action 5: Promote the obtention of funding for Spanish mathematics.
- Action 6: Study of the socio-economic impact of mathematical research and the transfer of technology in Spain.

Actions 2 and 5 directly drive the strategic positioning of mathematics in Spain in different spheres. The objective of Actions 1 and 6 is to carry out a thorough assessment of the current situation regarding the scientific and economic impact of mathematics in Spain, as a basis for its future empowerment. In 2019, the REM issued the following reports on the state of Spanish mathematics:

- First of all, the <u>Report on the socio-economic impact of</u> <u>mathematical research and technology in Spain</u> was issued. This is the first study to assess the mathematical intensity of the Spanish economy and was drawn up by the Analistas Financieros Internacionales (Afi) at the request of the REM. The work translates the amount of mathematics used in business activity into GDP and employment. The main conclusions of the report are as follows:
 - In Spain, mathematics is directly responsible for 6% of employment, while in the United Kingdom, France and Holland this figure -scillates between 10% and 11%.
 - If the direct and indirect impact of mathematics on other economic activities in Spain is added to this figure, it amounts to 19.4% for employment and 26.9% for the GDP.
 - Spanish businesses employ few high intensity mathematics professionals, either as specialists in database, finance or software design. These are the most highly productive and high growth occupations, even though they figure lower in Spain (0.47% annually) compared with the 15 Europe (0.59% annually).
 - If Spanish businesses had the same proportion of science and engineering graduates as in France, work productivity would increase by 2.2%.
- The Study on the scientific and economic impact and generational handover due to mathematics report was issued at the end of the year. This report addresses the production and scientific impact of mathematical research in Spain, a continuation of a study undertaken by Carlos Andradas and Enrique Zuazua on Spanish production in terms of mathematical research during the last decade of the 20th century. The report analyzes production over the 2000-2017 period and its scientific impact (impact of the journals in which papers were published and their number of citations). The sources of information used were the MathSciNet and Clarivate Analytics databases (mainly, InCites).

On the basis of the information provided, one may observe that among the 10 countries with highest mathematical production as recorded in "Web of Science" over the 2000-2017 period:

- Spain occupied the 6th position in percentage of papers cited.
- Spain occupied the 8th position in terms of the number of papers worldwide in the top 10% of the most cited.
- Spain occupied the 7th position in terms of citations per paper.
- Spain occupied the 7th position in terms of relative impact worldwide.

One possible conclusion that one may draw from this is that Spain, despite being well placed with regard to scientific impact, the number of highly influential papers (whose indicator would be the top 10 of the most cited), is not commensurate with global impact.

Furthermore, the second part of the report, which exhaustively studies the situation of mathematics in Spanish universities, and specifically the requirements of generational handover in Spanish mathematics, data is provided on the notable increase in the figures referring to enrolment in Mathematics and Statistics degree courses for the 2014-2017 period. It is striking to observe that the number of students enrolled in Mathematics rose, while at the same time the economy suffered a decline (2008-2012). Fortunately, when the economy seems to recover with a fall in the number of unemployed, university enrolment in mathematics does not go down, and interest in it has been maintained. This is likely due to the demand for mathematics graduates who are thinking about specializing later on in data science or doing a double degree in mathematics linked with the new technologies, professional profiles that are currently much sought after.

One deduces from this dual study that, while mathematical research in Spain has continued to grow strongly in recent decades, an evident danger exists that this research potential may decline due to the lack of generational handover. This entails the need to adopt the appropriate measures before such a foreseeable scenario starts to appear.

These two reports were presented at two different events. The first was held on April 10th, 2019, in Madrid, which was attended by the Minister for Industry, Commerce and Tourism, María Reyes Maroto; business leaders from various sectors, and a broad representation of the mathematical research community. This report was subsequently presented in cities throughout Spain.

SOMMa



SOMM Alliance presentation

Since October, 2017, the ICMAT has formed part of an alliance between the Severo Ochoa centres and the María de Maeztu Units, known as <u>SOMMa</u>. The main objective of this network is to promote Spanish excellence in research and to expand its social impact at a national and international level. In addition, it seeks to stimulate participation in outreach activities aimed at key sectors of society, such as the media, the scientific community, politicians and policy makers and the public in general; to promote the exchange of scientific knowledge, technology and best practice, both in and outside the network, and with the scientific community worldwide, thereby facilitating interdisciplinary collaboration and the proliferation of excellence; to support and contribute to scientific policy in Spain and internationally; to attract and integrate talent and to foster mobility in Spain; to find synergies and opportunities to collaborate with other research institutes and universities, with the aim of boosting Spanish science.

Throughout 2019, the Alliance conducted the following strategic activities:

- The first <u>SOMMa meeting on gender equality policies in</u> <u>science</u>. October 29th, 2019, CNIO (Madrid).
- <u>100xCiencia.4</u>: What is science doing for you? November 22nd-23rd, 2019, *Centro internacional de cultura contemporánea Tabakalera* (San Sebastian). Among the 18 talks on the schedule, Alberto Torres of the ICMAT spoke about the applications of mathematics to the new developments in big data, such as the design of self-drive cars.
- <u>SOMMa day session on Open Science</u>. April 8th, 2019. Universitat Pompeu Fabra (DTIC UPF).
- <u>Meeting</u> between the Severo Ochoa and the María de Maeztu institutions, the autonomous communities and the Minister for Science and Innovation. September 9th, 2019, Ministry of Science and Innovation (Madrid).
- The first formal <u>meeting</u> between Pedro Duque, the Minister for Science and Innovation, and representatives of SOM-Ma. February 11th, 2019, ALBA synchrotron (Barcelona).

Red de Divulgación Matemática (DiMa)



DiMa presentation

The Red de Divulgación Matemática (DiMa – Mathematical Outreach Network) is a platform consisting of disseminators of mathematics in Spain and enjoys the support of institutions (universities and research centres) and mathematical societies, among which is the ICMAT. The DiMa is a cooperative space for the sharing of experiences, materials, learning and reflection on mathematical outreach.

In 2019, the network organized "Learn to disseminate," the first training course on mathematical outreach, which was held between June 25th-28th in Castro Urdiales and brought together experts in this area, such as Claudi Alsina, Raúl Ibáñez and Clara Grima, who gave specific courses on the use of various tools for communication in mathematics. Ágata Timón G Longoria, head of the ICMAT Outreach and Communication Office, conducted a session on the communication of science at scientific institutions.



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 Insua, 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.

In 2019, the following activities were undertaken at the AXA Chair in Adversarial Risk Analysis:

Congresses

- "Cyber Insurance and its Contribution to Cyber Risk Mitigation"
 - March 25 29
 - Lorentz Center (Leiden, Netherlands)
 - <u>Web</u>
- GDRR 2019: "Sixth Symposium on Games and Decisions in Reliability and Risk"
 - May 29
 - George Washington University (Washington, EE. UU.)
 - <u>Web</u>
- BISP11: "Eleventh Workshop on Bayesian Inference in Stochastic Processes"
 - June 12 14
 - Real Academia de Ciencias (Madrid, Spain)
 - <u>Web</u>
- "Advances in Decision Analysis 2019. DATA 2019"
 - June 19 21
 - Bocconi University (Milan, Italy)
 - <u>Web</u>
- BIS 2019 Conference: "ISBIS Young Business and Industrial Statisticians Workshop on Recent Advances in Data Science and Business Analytics"
 - September 25 29
 - Mimar Sinan Fine Arts University (Istanbul, Turkey)

Seminars and courses

<u>Courses</u>

- Course: "Games and Decisions in Reliability and Risk," 6 th GDRR SAMSI Openning workshop 2019
 - 2019 2020
 - SAMSI (The Statistical and Applied Mathematical Sciences Institute), Raleigh (USA)
 - <u>Web</u>
- Course: "Machine Learning"
- Spring 2019
 - Instituto Nacional de Estadística (Madrid, Spain)

Seminars

- Seminar: "Mét-d-s Bayesian-s y Big Data"
 - February 8
 - Universidad de Las Palmas de Gran Canaria (Spain)
 - More information
- Inter-Reales Academias Inteligencia Artificial Session: "El valor de los datos" (Intelligence and Data for Security and Cybersecurity)
 - June 19
 - Real Academia de Ciencias Exactas, Físicas y Naturales, Real Academia Nacional de Medicina, Real Academia de Ingeniería (Madrid, Spain)
 - <u>Web</u>
- Adversarial machine learning: "(Almost) everything about adversarial machine learning"
 - october 11
 - Universidad Politécnica de Madrid (Spain)
 - More information
- Seminar: "Synge's Geometric Mechanics and Kinetic Theory"
 - october 21 25
 - ICMAT (Madrid, Spain)
 - More information

Thesis

• "Decision models for cybersecurity," Aitor Couce Viera, URJC. September 2019

Training contracts

• IND2018/TIC-9901. Funding for industrial doctorates in the Community of Madrid, in response to the Community of Madrid 2018 call for applications. Participants: ICMAT, Aeronautical Energy Engineering Services S.L. Beneficiary: Bruno Flores Barrio. ICMAT Budget estimate: 60,000 (25/02/2019 - 24/02/2022). PEJD-2018-POST/TIC-9375. Membership contract to the Spanish System of Science, Technology and Innovation for the promotion of the employment of young people and the deployment of the Community of Madrid *Garantía Juvenil*. Beneficiary: David Gordo. ICMAT Budget estimate: 35,000 (16/03/2019 - 15/03/2020).

Funding

• Mobility funding for short stays at foreign centres for beneficiaries belonging to the University Teacher Training Subprogramme. Beneficiary: Víctor Gallego Alcalá. Amount: 5,160. Destination: Duke University (USA).

Awards

• Edelman Award 2019 (finalist).

International consortiums

In 2019, the ICMAT participated in three 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>

Building Acceptance and Trust in Autonomous Mobility (TRUSTONOMY)

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

Participant: David Ríos Insua (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 will be 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>

• Supporting Cyberinsurance from a Behavioural Choice Perspective (CYBECO)

Duration: 1/05/2017 - 30/04/2019

Principle Researcher: David Ríos Insua (ICMAT)

A project aimed at analyzing and designing future cyberinsurance in the framework of cybersecurity.

<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 Insua, participates in the AIHub, the platform that designs the strategic plan of CSIC activities in the field of Artificial Intelligence (AI).

Moreover, in 2019 the members of DataLab were responsible for in the Games, Decisions, Risk and Reliability section of the <u>SAM-</u> <u>SI</u> (Statistical and Applied Mathematical Sciences Institute) programme, formed by Duke University, the North Carolina State University (NCSU) and the University of North Carolina (UNC) in Chapel Hill. It also forms part of the National Science Foundation (NSF) Division of Mathematical Sciences.



IMPRESSIVE meeting at the ICMAT



12.Communication and outreach activities

Throughout 2019, the ICMAT continued its intense outreach and communication activity through the Communication and Outreach Office, formed by Laura Moreno Iraola and Ágata Timón G Longoria, with advice and support from Daniel Peralta, Alberto Enciso, Javier Aramayona, David Martín de Diego, José María Martell and Antonio Córdoba. 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 Science Week and Matemáticas en la Residencia. A full list of the activities is as follows:

ICMAT Newsletter

The ICMAT publishes a news <u>bulletin</u> 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.

One issue of the ICMAT newsletter was published in 2019:

Newsletter #18

Press releases





EDITORIAL

Un nuevo año ha comenzado haciéndonos particularmente conscientes de la importancia del CIMAT como "casa de las matemilicas" abierta a las comunidad internacional. Este mismo nevelistro informa sobre algunos de los resultados más inter-santes contenes subhyvar que la influencia de un centro como el ICMAT irá siempor mucho más allá de la mera relación de las publiciaciones de subvar que la influencia de un centro como el ICMAT irá siempor mucho más allá de la mera relación de las publitados, proyectos y colaboraciones que se originan en nuestras dependencias y que inscritican Lego, liempo despuis, muchas veces lejos de nuestra casa. El eljetivo primoridal del ICMAT es en presenmiento original que produce avances decisivos en la ciencia, que innegueze nuestra conscimiento de la naturaleza y time aplicaciones a menudo insospechadas.

emiquee indexino consolutionistis de la induitada y viente aplocaciones as minudo inosopechadas. La adsocripción para los próximos cuatro años de los miemboros (lacici/l), pertenencientes a las tres outiversidades de limitatuo, en aprobación por parto de la Comisión Rectora de la proyuesta da aborada por la Comisión Mata Icompuesta por las universidades el CSCL; y que nature de la Comisión Rectora de la proyuesta da aborada por la Comisión Mata Icompuesta por las universidades planta las enteracionas quientes repetors su pertenencia el Indatuo ción contribuirán a que el ICMAT siga navegando viento en popa para sentimos optimistas respecta ao sucientado el contribuirán a que el ICMAT siga navegando viento en popa para sentimos optimistas respecta da su indica las colicitad de tercer galardón de excelencia Sivero Ochaa. Tenemos raziones para sentimos optimistas respectado por el Ministerio de Ciencia Innovación y Universidades. No podemos, sin embargo, confiarmantener las actividades ella Instituto.

mantener las actividades del Instituto. El proceso de adsoriçaión, previato en los estatutos, ha puesto de manificati una estensible faita de simetria entre el CSIC y bas tres universidades IUAN. UCH y UCM. Se trata de una sunto de hondo calado que será conveniente reconsiderar en una próximresisán de los estatutos y del convenio. La asimetria se manifiesta también en los numeross traimies humoralitos a los que el Instituto se se semetido per parte del CSIC, que intensidad es muy superior a la demandade por las otras tres instituciones. La reciente reestruturaria del las árreas del CSIC es también motivo de preocupación, por cuanto inigán matemático forma parte de la Comisión de materio, que es en la que estamos encuadrados y tiene a su cargo decisiones sobre nuevos puestos parte des la comisión.

1





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 2019, 19 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



Café y Teoremas' is a weekly publication coordinated by the IC-MAT and published in the section entitled Materia of the *El País* 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. They also highlight those to whom we owe these developments and how they transformed them from coffee into theorems. 39 articles appeared in 2019. The full list of articles is as follows:

- "<u>Matemáticas alrededor de la tabla periódica,</u>" Antonio Córdoba (ICMAT-UAM). January 4.
- "Jean Bourgain, el barón de los 'problem solvers'," Keith Rogers (ICMAT-CSIC). January 11.
- "<u>Muere Michael Atiyah, uno de los más grandes matemáticos de nuestro tiempo,</u>" Oscar García-Prada (ICMAT-CSIC). January 18.
- "<u>Gödel y los límites de las matemáticas,</u>" Elías Baro González (UCM) and Amador Martín Pizarro (Albert-Ludwig University). January 25.
- "Maria Agnesi, la gran matemática de la Ilustración," Laura Moreno Iraola (ICMAT-CSIC). February 1.
- "El problema de distinguir dos fórmulas químicas iguales," Marta Macho-Stadler (UPV/EHU). February 8.
- "Sofía Kovalevskaya, la primera matemática profesional," Michéle Audin (Universidad de Estrasburgo). February 11.
- "<u>Campos magnéticos en una taberna escocesa</u>," Alberto Enciso (ICMAT-CSIC) and Daniel Peralta (ICMAT-CSIC). February 27.

- "<u>Karen Uhlenbeck, pionera y matemática 'imperfecta',</u>" Leonor Ferrer Martínez (Universidad de Granada, RSME). March 19.
- "<u>Emmy Noether, la fundadora del álgebra moderna,</u>" Ana Bravo (ICMAT-UAM). March 27.
- "<u>Matemáticas para describir las vibraciones de las molécu-</u> <u>las,</u>" Florentino Borondo (ICMAT-UAM). April 12.
- "Las matemáticas que mejoran los sistemas europeos de <u>navegación por satélite</u>," Esther Sardón Pérez (Sistema Operacional de Galileo de la empresa GMV). April 17.
- "<u>Trenzas matemáticas para guardar secretos</u>," Yago Antolín (ICMAT-UCM) and Delaram Kahrobaei (York University). May 8.
- "Los matemáticos borran el nombre de un filonazi en uno de sus premios," Antonio Córdoba (ICMAT-UAM). May 15.
- "<u>El molinero que revolucionó el electromagnetismo</u>," Ignacio del Amo (ICMAT). May 24.
- "Que no te den gato por liebre... ¿o sí?," Víctor Gallego (IC-MAT-CSIC), David Gordo (ICMAT-CSIC) and Roi Naveiro (IC-MAT-CSIC). June 7.
- "<u>Desarrollar el sentido espacial para comprender el mun-</u> <u>do,</u>" Rafael Ramírez (Universidad de Granada). June 12.
- "<u>Un matemático ruso desmiente una conjetura con más de</u> <u>medio siglo de vida,</u>" Alberto Márquez (Universidad de Sevilla) and Ágata Timón (ICMAT-CSIC). July 5.
- "Ganar juegos usando la mecánica cuántica," Julio de Vicente (UC3M), Fernando Lledó (ICMAT-UC3M), Diego Martínez (ICMAT-UC3M) and Carlos Palazuelos (ICMAT-UCM). July 12.
- "<u>Réquiem por el último matemático universal</u>," Alberto Enciso (ICMAT-CSIC) and Daniel Peralta (ICMAT-CSIC). July 19.
- "<u>Matemáticas para descifrar el sentido del olfato,</u>" Carlos Conca (Universidad de Chile). July 26.
- "<u>Vida (matemática) de una gota,</u>" Marco Fontelos (IC-MAT-CSIC). August 2.
- "<u>Resuelto un famoso problema matemático en dos páginas condensadas en un tuit,</u>" Albert Atserias (Universitat Politècnica de Catalunya). August 9.
- "¿Pueden las matemáticas desbloquear la situación política?," Luis Ángel Calvo Pascual (Escuela Técnica Superior de Ingeniería ICAI). August 16.
- "Los papeles que un genio matemático no pudo quemar," David Fernández (Universidad de Bielefeld) and Ágata Timón (ICMAT-CSIC). August 22.
- "<u>María Wonenburger, la matemática que saltó a la fama con</u> <u>80 años,</u>" Laura Moreno Iraola (ICMAT-CSIC). August 27.
- "<u>Series que te acercan a las matemáticas,</u>" Ignacio del Amo (ICMAT). September 3.
- "<u>Un matemático ligado a una enigmática hipótesis</u>," Fernando Chamizo (ICMAT-UAM) and Ágata Timón (ICMAT-CSIC). September 13.
- "<u>Un modelo matemático realista para explicar la visión</u>," Gemma Huguet (UPC). September 20.
- "<u>Los datos matemáticos del cambio climático,</u>" Chris Budd (Bath University). September 27.
- "<u>Posiblemente, la conjetura más importante de la relatividad general,</u>" Ágata Timón (ICMAT-CSIC) and Alberto Soria (ICMAT-Universidad Católica de Ávila). October 11.

- "¿<u>Es 3,14 una buena aproximación de Pi?</u>," Ágata Timón (ICMAT-CSIC) and Daniele Casazza (ICMAT). October 21.
- "<u>Cuando el primer ministro de Italia era un matemático,</u>" Piergiulio Tempesta (ICMAT-UCM). October 30.
- "Qué es la teoría de categorías y cómo se ha convertido en tendencia," John Baez (California Riverside University, Center for Quantum Technologies, Singapore). November 8.
- "<u>Redes matemáticas para garantizar la seguridad de las</u> <u>'apps'</u>," Kristin Lauter and Ágata Timón (ICMAT-CSIC). November 14.
- "¿Nos podemos fiar de los modelos matemáticos del cambio climático?," Chris Budd (Bath University). December 6.
- "No es posible diseñar un método matemático para ganar la Lotería de Navidad," Ágata Timón (ICMAT-CSIC). December 13.
- "<u>Una conjetura para controlar todos los espacios,</u>" Francisco Presas (ICMAT-CSIC). December 18.
- "<u>Campana sobre campana (matemática)</u>," Yago Antolín (ICMAT-UCM) and Carolina Vallejo (ICMAT-UAM). December 23.

News stories

The ICMAT regularly publishes <u>news stories</u> on its website about the scientific and outreach activity conducted at the centre. In 2019, 60 news stories were published.

Blog

<u>The ICMAT Blog</u> 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 2019, 14 articles appeared on this blog.

Social networks

The ICMAT maintains active profiles on the main social networks. The number of followers as of December, 2019, is shown below:

- Facebook: 28 034 followers, 27 092 likes
- <u>Twitter</u>: : 24 950 followers
- Instagram: 2900 followers
- YouTube: 1351 subscribers; 49 646 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

February 11, International Day of Women and Girls in Science

The ICMAT has joined in celebrating February 11, International Day of Women and Girls in Science with different activities:

Workshop: "Women mathematicians"

On February 6, Ana Bravo, UAM lecturer, chair of the ICMAT Gender Comission and member of the Institute, gave a workshop for secondary school students, during which the work of women mathematicians, especially in arithmetics and geometry, was presented.



Workshop "Women mathematicians," given by Ana Bravo.

Escape Road: "In search of Nobel and non-Nobel women scientists"

This activity consisted of a treasure hunt held from February 4th to February 18th at the Campus de Cantoblanco, devoted to women scientist Nobel prize-winners and also to winners of a Fields Medal, which is regarded as equivalent to a Nobel Prize in mathematics, as well as other women scientists whose great discoveries were not recognized with either of these prizes.

The event was organized by the gender commissions belonging to the following CSIC centres: the Madrid Institute of Material Sciences, the Institute of Ceramics and Glass, the Institute of Catalysis and Petrochemistry, the National Center for Biotechnology, the Severo Ochoa Center of Molecular Biology, the Institute of Mathematical Sciences, the Institute of Theoretical Physics, The Institute for Research in Food Sciences, the Institute of Micro and Nanotechnology and the National Center for Microelectronics.



Maryam Mirzakhani was one of the women scientists who were included in the Escape Road "In search of Nobel and non-Nobel women scientists."

"4º ESO + EMPRESA"

The ICMAT participates annually in the Community of Madrid 49 <u>ESO+Empresa</u> programme, which offers educational stays with companies and research centres for young students. Over a period of three days, the pupils are introduced to the day-to-day activities of the Institute for the purpose making them aware of mathematical research as a viable career choice, as well as showing them the daily work of mathematical scientists and the path to follow to arrive at that point. In the 2019 edition, celebrated on April 1, 2 and 3, the ICMAT hosted 30 pupils from schools in Madrid, suchs as the IES Marqués de Santillana (Colmenar Viejo), the IES María Zambrano (Leganés), the IES Federico García Lorca (Las Rozas) and the IES Cervantes (Madrid).

ICMAT researchers and personnel participated by giving different workshops and talks.

"European Researchers' Night"

The ICMAT celebrated the <u>European Researchers' Night 2019</u> by means of a joint activity with MediaLab Prado (Madrid), which was held on September 27. The Institute directed the "Mapas y Mates" ["Maps and Maths"] workshop in which a seemingly simple question was posed, but one that has intrigued mathematicians for decades: the four-colour problem. Jezabel Curbelo,lecturer at the Autonomous University of Madrid and ICMAT member, and Marco Castrillón, lecturer at the Complutense University of Madrid, were in charge of conducting this activity, with the support of the ICMAT Unit of Scientific Culture.

The ICMAT collaborated in activities coordinated by the different CSIC centres, most of which took place on the Campus de Cantoblanco and throughout the day at the MediaLab Prado cultural centre. There were also activities aimed at schools during the morning and early afternoon, which were also open to the public in the afternoon sessions.

The ICMAT also participated in the Escape Road: "A la búsqueda de las científicas Nobel y no Nobel," a route consisting of interactive panels and challenges representing the life and work of women Nobel Prize winners in the different branches of science, as well as women winners of Fields Medals (equivalent in mathematics to the Nobel Prize), together with those overlooked for these awards.



Workshop "Maps and maths"

"Science in Action"

"<u>Science in Action</u>" is a competition based on innovative ideas for bringing science closer to the general public. Those selected in the first (distance) 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 competition took place on October 4-6 in Alcoy (Alicante).

The fair is a platform for spectacular and surprising projects of scientific dissemination designed to fascinate the audience.

"Mathematics at the Residencia"

"<u>Mathematics at the Residencia</u>" 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 2019, the following talk was organised:

"Las matemáticas del deporte," by Tom Crawford (Tom Rocks Maths - University of Oxford) Date: November 12, 2019 Place: Residencia de Estudiantes (Madrid) More information



Tom Crawford during his talk.

"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.

In 2019, the Institute organised two activities for secondary school students in collaboration with the Centro Cultural Pablo Iglesias de Alcobendas (Madrid), held on November 5:

Conference: "Cuando el espacio se curva." Speaker: Javier • Aramayona (ICMAT-UAM)





Javier Aramayona in his talk.

Workshop: "Mapas y mates." David Martín de Diego (IC-MAT-CSIC). Ágata Timón (ICMAT-CSIC) and Laura Moreno Iraola (ICMAT-CSIC)



Secondary students during the workshop "Maps and maths."

The "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 2019:

- Las matemáticas de la biología, Manuel de León (ICMAT-CSIC) and Antonio Gómez Corral (UCM). January 2019.
- Geometría y moda. Secretos matemáticos del vestir, Claudi Alsina. January 2019.



- Demostraciones visuales en matemáticas. Ver para pensar, Ana Carvajal Sánchez and José Luis Muñoz Casado (FESPM). June 2019.
- Los secretos de la multiplicación, Raúl Ibáñez (UPV-EHU). September 2019.







<u>Una mirada distinta de las</u> matrices. Viajes, retos y magia, Mireia López Beltrán and Pura Fornals Sánchez (FESPM). November 2019.

School visits

The ICMAT regularly opens its doors to school groups of different educational levels in order to show them at first-hand how mathematical research is conducted.

In 2019, the Institute organised this visit:

• "¿A qué te imaginas que se dedica un investigador en matemáticas?" Speakers: José María Martell, director of the ICMAT, and Florentino Borondo (ICMAT-UAM), February 28.

More information



José María Martell introducing the ICMAT.



Graphic communication

The ICMAT Communication Office is responsible for preparing posters for the different activities that take place at the Centre in order to assist and facilitate their publicity and diffusion. Almost 250 of such posters were designed in 2019.













IC





13.Gender Commission

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 <u>Gender Commission</u>, which demonstrates the institutional commitment of the ICMAT to equality in general.

The aims of the commission are as follows:

- To stimulate the participation of women in the ICMAT programmes of research and outreach.
- To promote the access of women to decision-making positions in the ICMAT.
- To provide a working environment in which women feel welcomed and appreciated.
- To raise the visibility of women mathematicians and to provide role models of women mathematical researchers at the highest level, both in the eyes of the general public and especially of students.
- To contribute to the awakening of mathematical vocation in girls.
- To join national and international initiatives for gender equality.
- To promote the leadership of African women in scientific research and the transfer of technology, and to strengthen the capacity of research centres in their countries of origin.

In 2019, the Gender Commission consisted of the following members: Ana Bravo (ICMAT-UAM, chairperson); Javier Aramayona (ICMAT-UAM); Eva Gallardo (ICMAT-UCM); Marta Macho Stadler (UPV/EHU); David Martín de Diego (ICMAT-CSIC); Laura Moreno Iraola (ICMAT-CSIC); Edith Padrón (ULL) 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 plan is structured around three courses of action:

- Outreach activities: Activities designed to stimulate the vocation of women mathematicians and education for equality. Competitions, talks, roundtable discussion, workshops, etc..
- Communication activities: In addition to maintaining a gender perspective in all the ICMAT public communications, content is also provided in the Newsletter and in other channels at the centre, as well as the website, to showcase the work of women mathematicians.
- Institutional action: The presence of women on the ICMAT committees, mentions in ICMAT calls, presence and/or collaboration of the ICMAT on gender commissions of other institutions.

The Gender Commission organized or collaborated with the following activities in 2019:

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

For four consecutive years, the ICMAT has participated in the "Science by Women" programme 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 to collaborate with ICMAT researchers in accordance with their fields of research. Thus, in 2019, from June to September, Latifa Debbi (National Polytechnic School of Algiers) completed her second research stay at the ICMAT.



Latifa Debbi

"My favourite woman scientist"

"My favourite woman scientist" is an initiative aimed at 5th and 6th year primary school pupils from all over Spain, with the purpose of providing role models that dispel gender prejudice and encourage scientific vocation in both girls and boys. In its first phase, a competition was devised in which the pupils investigate the lives and professional careers of women scientists, and subsequently complete a graphic assignment on the basis of what they have learned. The schools themselves make an initial submission of the candidates' work, and a panel consisting of members of the ICMAT Gender Commission make the final selections that are published in a book about women scientists.

The assignments are supplemented with a written work on the scientific contributions made by these women researchers, anecdotes from their lives and key events in their careers. The resulting catalogue is conceived for scientific outreach purposes and is designed to promote equality and scientific vocation. It is distributed in hard copy among the participating schools and is made available in a digital format that can be downloaded from the ICMAT website.

46



The latest version of this activity was conducted during the 2018-2019 school year. In this third edition of the project, 21 new names were added to the 61 favourite women scientists chosen in the two previous editions in which some ten different schools participated. A hard copy was published and can also be downloaded in digital format from the ICMAT website. ICMAT.



"Mi científica favorita 3" front page

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

- Workshop: "Women mathematicians." More information, page 42.
- Videos: 11 F. Various videos were made during 2019 to celebrate February 11th. Each one featuring a women researcher in mathematics at different stages of her career. The videos show what induced them to choose a profession in research; what they like the most about the work and the difficulties they have encountered throughout their careers for the fact of being a woman. The videos were distributed through the ICMAT social network profiles.
- "Escape Road. In search of Nobel and non-Nobel women scientists." More information: page 43.

Dialogues on Gender and Science: "A conversation with researcher Hara Charalambous"

On October 16th, 2019, the <u>third meeting in this series of Dialogues</u> took place, during which two researchers, Hara Charalambous from the Aristotle University of Thessaloniki (Greece) and Ana Bravo, chairperson of the ICMAT gender Commission, professor at the UAM and a member of the ICMAT, held on open conversation with degree students of mathematics about their research work and their professional careers, etc.



Hara Charalambous (right) and Ana Bravo during the dialogue.

"She does maths," ICMAT Newsletter

This 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 "*Mujeres con Ciencia*." 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.

Debate: "Women and mathematics," as part of the 4° de ESO + Empresa programme

The ICMAT participates in the Community of Madrid "4ESO+empresa" programme, which provides 4th-year Secondary School students with the opportunity to do short-term educational stays at companies and research centres. The 2019 programme was held between April 1st and April 3rd and included an activity organized by the ICMAT Gender Commission with the aim of raising the awareness of the participating students of the inequality that exists in the sphere of mathematics. Audiovisual documentaries on the work of women mathematicians from different parts of the world were shown, which were later followed by a debate on the issue. The debate was moderated by Eva Gallardo, professor at the UAM, a member of the ICMAT and also of the centre's the Gender Commission.





C/ Nicolás Cabrera, nº 13-15 Campus Cantoblanco UAM 28049 Madrid, Spain www.icmat.es 57











