ICMAT

INSTITUTO DE CIENCIAS MATEMÁTICAS

Annual Report

2024

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CSIC Consejo Superior de Investigaciones Científicas

UAM Universidad Autónoma de Madrid

Universidad Complutense Madrid

uc3m Universidad Carlos III de Madrid

Excelencia Severo Ochoa diciembre 2011-marzo 2030

ICMAT Annual Report 2024

The Instituto de Ciencias Matemáticas (ICMAT, Institute of Mathematical Sciences) is a joint research centre of the Consejo Superior de Investigaciones Científicas (CSIC, Spanish National Research Council) and three Madrid universities: the Universidad Autónoma de Madrid (UAM), the Universidad Carlos III de Madrid (UC3M) and the Universidad Complutense de Madrid (UCM). ICMAT is a leading international research centre in mathematics, recognized by the Spanish accreditation of excellence Severo Ochoa.

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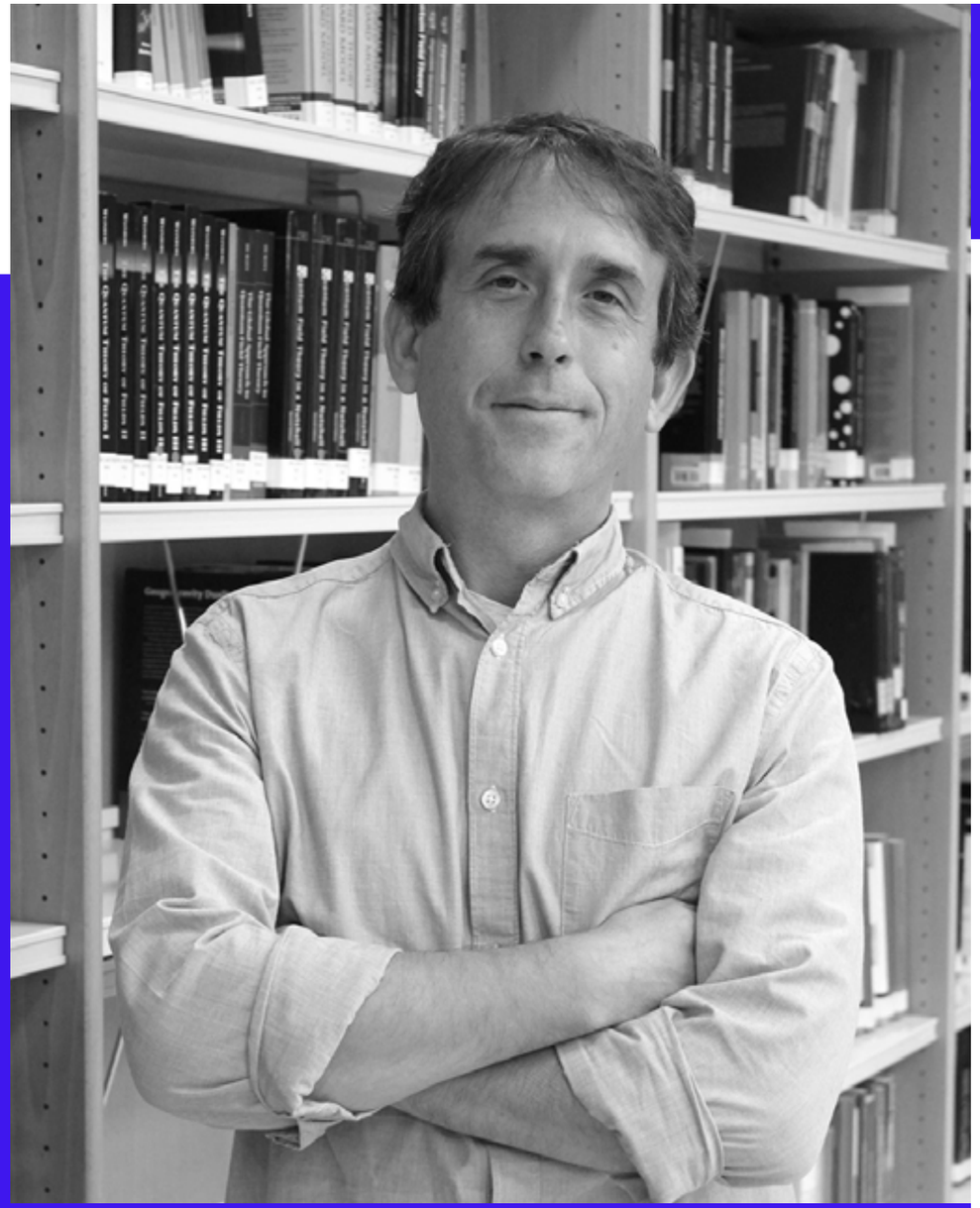


1. A MESSAGE FROM ICMAT'S DIRECTOR

The year 2024 has been marked by outstanding achievements for ICMAT which, together with its continuous growth, consolidate the institute's position as a global benchmark in mathematical activity.

One of the most significant successes has been the fourth consecutive accreditation as a Severo Ochoa Centre of Excellence by the Spanish Ministry of Science, Innovation and Universities, making ICMAT one of the two research centres in the country with the highest number of awards. This recognition, which was announced in July 2024 by Diana Morant, Minister of Science, Innovation and Universities, from ICMAT itself, highlights the centre's leadership in mathematical research in Spain, places it at the level of the best European institutes and underlines the quality and impact of its scientific work.

The Severo Ochoa programme also opens up new opportunities to promote innovative projects, some of which have already begun in 2024. These include the new edition of the Severo Ochoa Laboratories and the Distinguished Visiting Professors programme, both led by internationally renowned researchers, which will become pillars of the institute's scientific excellence. Added to this is 'Enhancing mathematical bridges between Spain and Latin America', a new programme of mathematical collaboration between Spain and Latin America channelled through ICMAT and the Institute of the Mathematical Sciences of the Americas at the University of Miami. Its aim is to facilitate the exchange of knowledge between research personnel in both areas and to support the training of young scientists, through activities, grants for research stays and other actions.

ICMAT's commitment to the development of the next generation of mathematical talent also translates into the investment of funds for pre-doctoral training. Along the same lines, in September 2024 the third edition of the Pequeño Instituto de Matemáticas (Little Maths Institute) was launched, with a record number of participants - more than 150 -, a creative and determined commitment to fostering mathematical vocations among pre-university students aged between 12 and 18.

Also, during 2024, our research staff obtained high-impact scientific results and were invited to share them in the most important forums of our discipline. On the other hand, it has been incorporated into management positions in various scientific structures, increasing ICMAT's institutional weight in different forums. These include the Executive Committee of the European Mathematical Society, ERCOM - the committee of research centres of the European Mathematical Society - and the SOMMa Alliance, made up of Spanish research centres and units accredited with the Severo Ochoa and María de Maeztu seal of excellence.

In short, this year has opened a new stage that places ICMAT in an optimal position to continue advancing in cutting-edge research and consolidating its status as a global leader in the field of mathematics.

2. FACTS AND FIGURES

5 moments of 2024

Eloísa del Pino, president of CSIC, visits CFTMAT (ICMAT+IFT)

February. She was accompanied by José María Martell, Vice-President for Scientific and Technical Research of CSIC and former Director of ICMAT, and Isabel Martínez, Cabinet Director of the Presidency of CSIC.

Launch of 'Enhancing mathematical bridges between Spain and Latin America'

April. This is a new ICMAT programme for the exchange of knowledge and support for training among research personnel from both areas.

ICMAT receives accreditation as a Severo Ochoa Centre of Excellence in four consecutive calls

May. The Ministry of Science, Innovation and Universities awards the prize to the best research centres in the country.

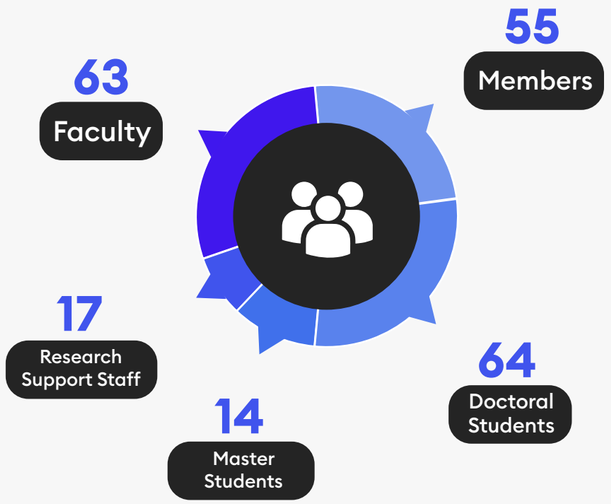
Diana Morant, Minister of Science, Innovation and Universities, visits ICMAT

July. During her visit, Morant announced the results of the Severo Ochoa and María de Maeztu calls and stressed that ICMAT "trains young mathematicians and does research that changes society"

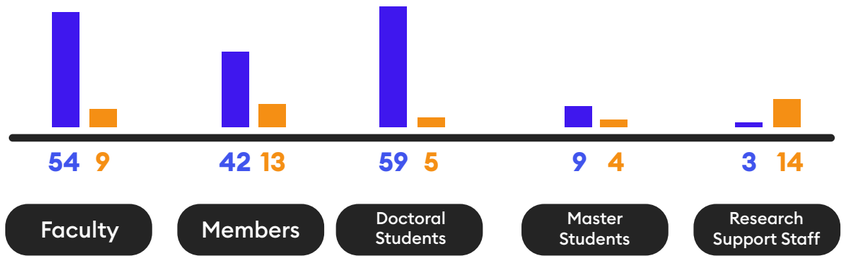
14 key figures in world mathematics join ICMAT

September. Two Fields medalists, a Shaw Prize winner, the 2006 Prince of Asturias Award for Technical and Scientific Research and the president of the Clay Institute of Mathematics, among the directors of the fourth edition of the Severo Ochoa Distinguished Visiting Professors and Laboratories.

PERSONNEL



Distribution by Gender



200
Scientific Articles

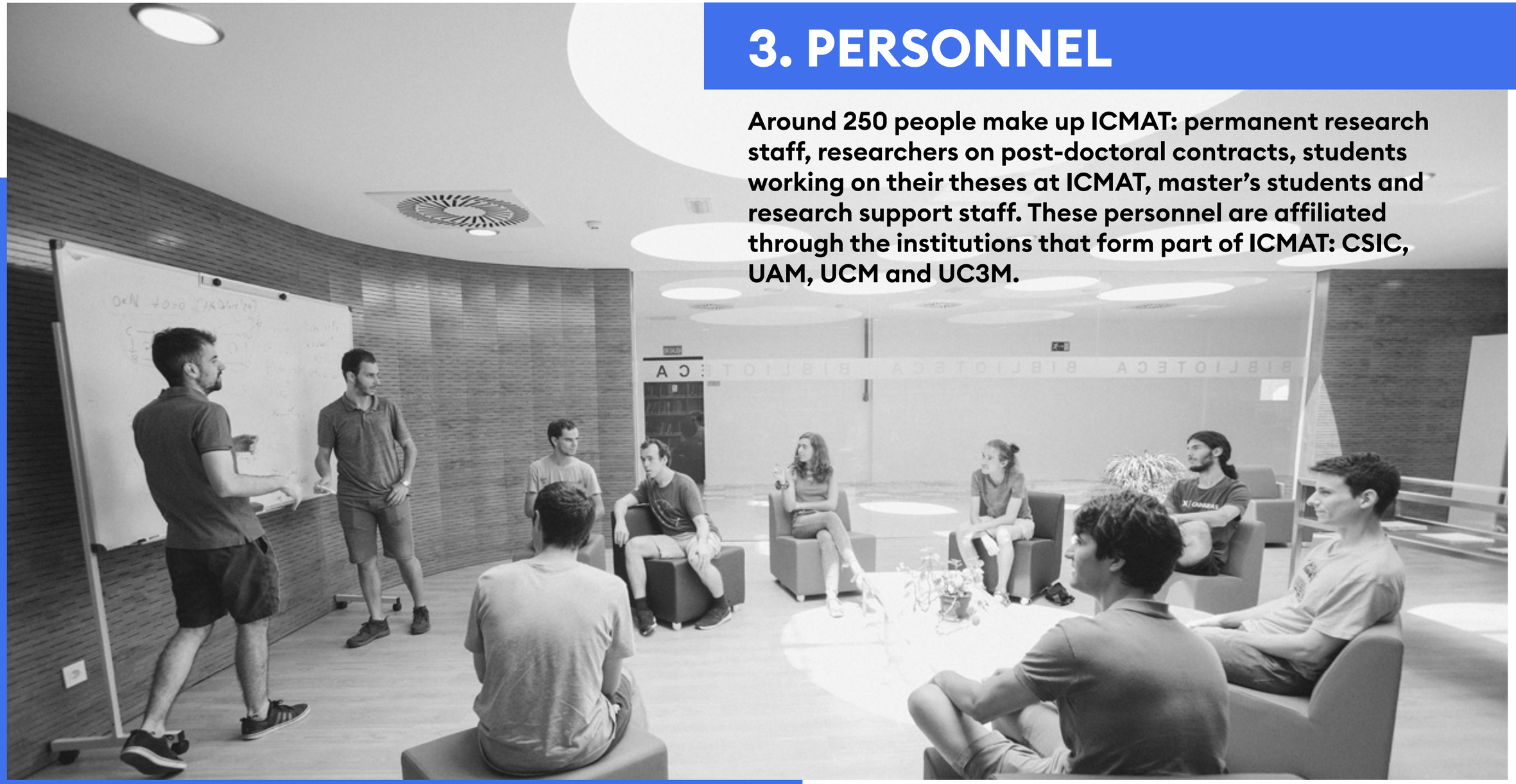
7
Theses

800
Visitors

ACTIVITIES

1	Thematic Research Programmes
14	Workshops
3	Schools
1	Distinguished Lectures
5	Special Colloquium
5	Joint Mathematics Colloquia (ICMAT-UAM-UC3M-UCM)
19	Joint Mathematics Junior Colloquium (ICMAT-UAM-UC3M-UCM)
11	Courses
109	Seminars
12	Working groups
20	Outreach activities

3. PERSONNEL



Around 250 people make up ICMAT: permanent research staff, researchers on post-doctoral contracts, students working on their theses at ICMAT, master's students and research support staff. These personnel are affiliated through the institutions that form part of ICMAT: CSIC, UAM, UCM and UC3M.

3.1. Research groups

The scientific staff of ICMAT is structured around three main research groups:

GROUP A: Algebra and Geometry
GROUP B: Mathematical Analysis and Differential Equations
GROUP C: Applied Mathematics

GROUP A: Algebra and Geometry

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

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 centres 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.

Faculty
Luís Álvarez Cónsul
Yago Antolín Pichel
Javier Aramayona Delgado
Nuno Ricardo Barroso De Freitas
Ana Bravo Zarza
José Ignacio Burgos Gil
Oscar Segundo García Prada
Mario García Fernández
Ernesto Girondo Sirvent
Manuel de León
Tomas Luis Gómez De Quiroga
Gabino González Díez
Enrique González Jiménez
Luis Guijarro Santamaria
Andrei Jaikin Zapirain
Ignacio Luengo Velasco
Daniel Macías Castillo
David Martin De Diego
Daniel Peralta Salas
Francisco Presas Mata
Piergiulio Tempesta
Orlando Villamayor Uriburu

Members
Benjamin Bode
Oliver Braeunling
Caterina Campagnolo
Federico Cantero Moran
María Inés De Frutos Fernández
Bogar Díaz Jiménez
Eva Elduque Laburta
Emilio Franco Gómez
Alejandra Garrido Angulo
Manuel Garzón Martínez
Federico Giusti
Jose Angel González Prieto
Ondrej Kubu
Marco Sebastian Linton
Leo Margolis
Beatriz Pascual Escudero
Arpan Saha
Amna Shaddad
María De La Paz Tirado Hernández

Doctoral students
Isidro Benayora Garzas
Néstor Blázquez Hernán-Gómez
Alejandro Calleja Arroyo
Javier Casado Álvarez
Bilson Castro López
José Antonio Castro Moreno
Iván Chércoles Cuesta
Andoni De Arriba De La Hera
Rodrigo Alonso De Pool Alcántara
Sergio Domingo Zubiaga
Guillermo Gallego Sánchez
Sergio García Rodrigo
Miguel González González
Manuel Lainz Valcazar
Alfredo Llosa
Juan Manuel López Medel
Asier López Gordon
Francisco Javier Martínez Aguinaga
Enrique Martínez Cardenal
Daniel Martínez Marqués
Daniel Martínez Marqués
Manuel Mellado Cuerno
Henrique Mendes Da Silva E Souza
Victoria Pelayo Alvaredo
Javier Peñafiel Tomás
Daniel Reyes Nozaleda
Diego Ruiz Cases
Pablo Sánchez Peralta
Guillermo Sánchez Arellano
Roberto Téllez Domínguez
Didac Violan Aris
Zhou Wei

Master students
Gabriel Abánades Joglar
Javier Aguilera Villegas
Natalia Averna García
Malena Domínguez Sirgo
Rubén Izquierdo López
Claudia Muñoz Jerónimo
Manuel Timiraos López

Associated members
Juan Carlos Marrero
Edith Padrón

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.

Faculty
José María Arrieta Algarra
Davide Barbieri
Matteo Bonforte
Pablo Candela Pokorna
María Jesús Carro Rossell
Ángel Castro Martínez
Fernando Chamizo Lorente
Diego Córdoba Gazolaz
Alberto Enciso Carrasco
Daniel Faraco Hurtado
Eva Gallardo Gutiérrez
María De Los Ángeles García Ferrero
María Del Mar González Nogueras
Jesús Ángel Jaramillo Aguado
José María Martell Berrocal
Carlos Mora Corral
Jesús Munarriz Aldaz
Rafael Orive Illera
Arturo De Pablo Martínez
Javier Parcet Hernández
Ana Primo Ramos
Fernando Quirós Gracián
Aníbal Rodríguez Bernal
Keith Mckenzie Rogers
Francisco Javier Soria De Diego
Pedro Tradacete Pérez
Antonio Córdoba Barba
Alberto Ruiz González

Members
Siddhant Govardhan Agrawal
Glenier Lázaro Bello Burguet
Mingming Cao
José Manuel Conde Alonso
Maximiliano Contino
Félix Del Teso Méndez
Jennifer Duncan
Antonio Jesús Fernández Sánchez
Claudia García López
Björn Gebhard
David Gómez Castro
Francisco Javier González Doña
Adrián González Pérez
Nastasia Grubic
Runan He
Salvador López Martínez
Teresa Elvira Luque Martínez
María Medina De La Torre
David Tobías Meyer
Marc Nualart Batalla
Yamilet Quintana
Javier Ramos Maravall
Guillermo Rey Ley
Alberto Salguero Alarcón
Tomás Sanz Perela
Clara Torres Latorre
Carlos Valero Sáez
Zhenguo Wei
Liu Zhen-Chuan
Fan Zheng

Doctoral students
Antonio Álvarez López
Itahisa Barrios Cubas
Norberto Clemente Delgado
David De Hevia Rodríguez
Laia Domingo Colomer
Joaquín Domínguez De Tena
Carlos Fuertes Morán
Alba Dolores García Ruiz
Enrique García Sánchez
Irene Gonzálvez Martínez
Pablo Hidalgo Palencia
Jorge Santiago Ibáñez Casado
Peio Ibarrondo Murguialday
Andrés Laín Sanclemente
José Antonio Lucas Manchón
Miguel Martínez González
David Muñoz Lahoz
Jorge Pérez García
Jorge Ruiz Cases
Omar Sánchez Antonio
Eduardo Tablate Vila

Master students
Francisco Unai Caja López
Alberto Caldera Morante
Álvaro Carballeira Mora
Pablo Molina Benito
Isabel María Moreno Cuadrado
Sofia Sirón Barluenga

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. This research includes topics such as microfluidics modelling and technological applications, geophysical fluid dynamics, etc.

Faculty
José Ramón Berrendero Díaz
Ana María Carpio Rodríguez
Antonio Cuevas González
Marco Antonio Fontelos López
Alberto Ibort Latre
Fernando Lledó Macau
Ana María Mancho Sánchez
Carlos Palazuelos Cabezón
David Pérez García
Carlos Rascón Diaz
David Ríos Insua
Nuria Torrado Robles
Julio Iñigo De Vicente Majúa
Ignacio Villanueva Diez

Members
Joan Claramunt Carós
Fabio Di Cosmo
Angelo Lucia
M. Eugenia Ulzurrun de Asanza Vega

Doctoral students
Pablo García Arce
Carlos García Meixide
Arnau Más Dorca
Pablo Páez Velasco
José Ramón Pareja Monturiol
Pablo Varas Pardo

Master students
Miguel Santos Pascual

3.2. Executive team and board

Executive team

Director:
Javier Aramayona

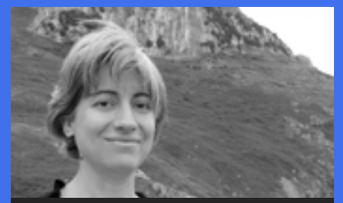


Image courtesy of Bravo

Deputy Director:
Ana María Bravo

Heads of Department


Image courtesy of Castro

Fundamental Mathematics: Ángel Castro

Applied Mathematics:
Piergiulio Tempesta

Board


Image courtesy of Arrieta

Personnel Representative:
José María Arrieta

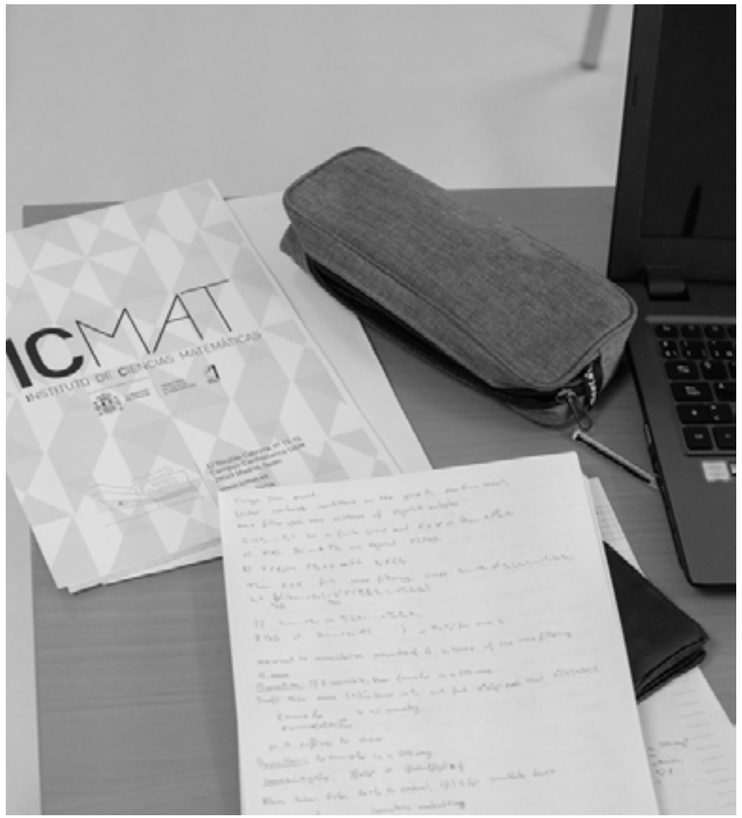
Personnel Representative:
José Manuel Conde

Personnel Representative:
Daniel Peralta

Secretary:
Clara García Suelto

3.3. Research Support Staff

ICMAT's research support staff enables to develop its own activities, internationalisation, knowledge transfer, outreach programme, etc. among others.



Administrative Office:
Marta Comas
Yolanda Fuentes
Natalia Potapova
Laura Rojas
Silvia Riaño
Esther Ruiz

ICT Office
Eduardo de Córdoba
Lucía Lafuente Roldán
Alfonso Núñez

Mahematical Culture Unit
Laura Moreno Iraola
Ágata Timón G. Longoria

Severo Ochoa Office
Esther Fuentes
Nadia Velasco

Project Management Office
Mónica Castresana (International projects)
Sara Sepulcre (National projects)

AXA Office
Marta Sanz González

CFTMAT is the Centre for Theoretical Physics and Mathematics, a service centre that handles management tasks affecting both ICMAT and Instituto de Física Teórica (IFT).

Management Department
Clara García-Suelto Huerta (Manager)
Concepción Cuenca Cuadrado (Human Resources)
Raúl García Concellón (Administration)
Nieves Martín González (Administration)
María Rabanal Martín (Administration)

'Jorge Juan' Library
Ricardo Martínez de Madariaga

3.4. External Scientific Advisor Committee

The External Scientific Advisory Committee is composed of eight distinguished internatio-nal mathematicians:


Image: FRS

Martin R. Bridson (Universi-ty of Oxford and Clay Mathema-tics Institute)

Jill Pipher (Brown University)

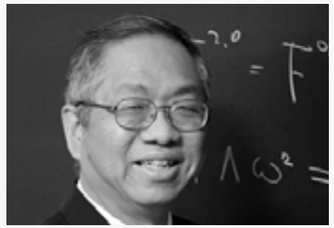
Luis Caffarelli (University of Texas at Austin)

Antonio Ros (Universidad de Granada)

Peter Constantin (Princeton University)

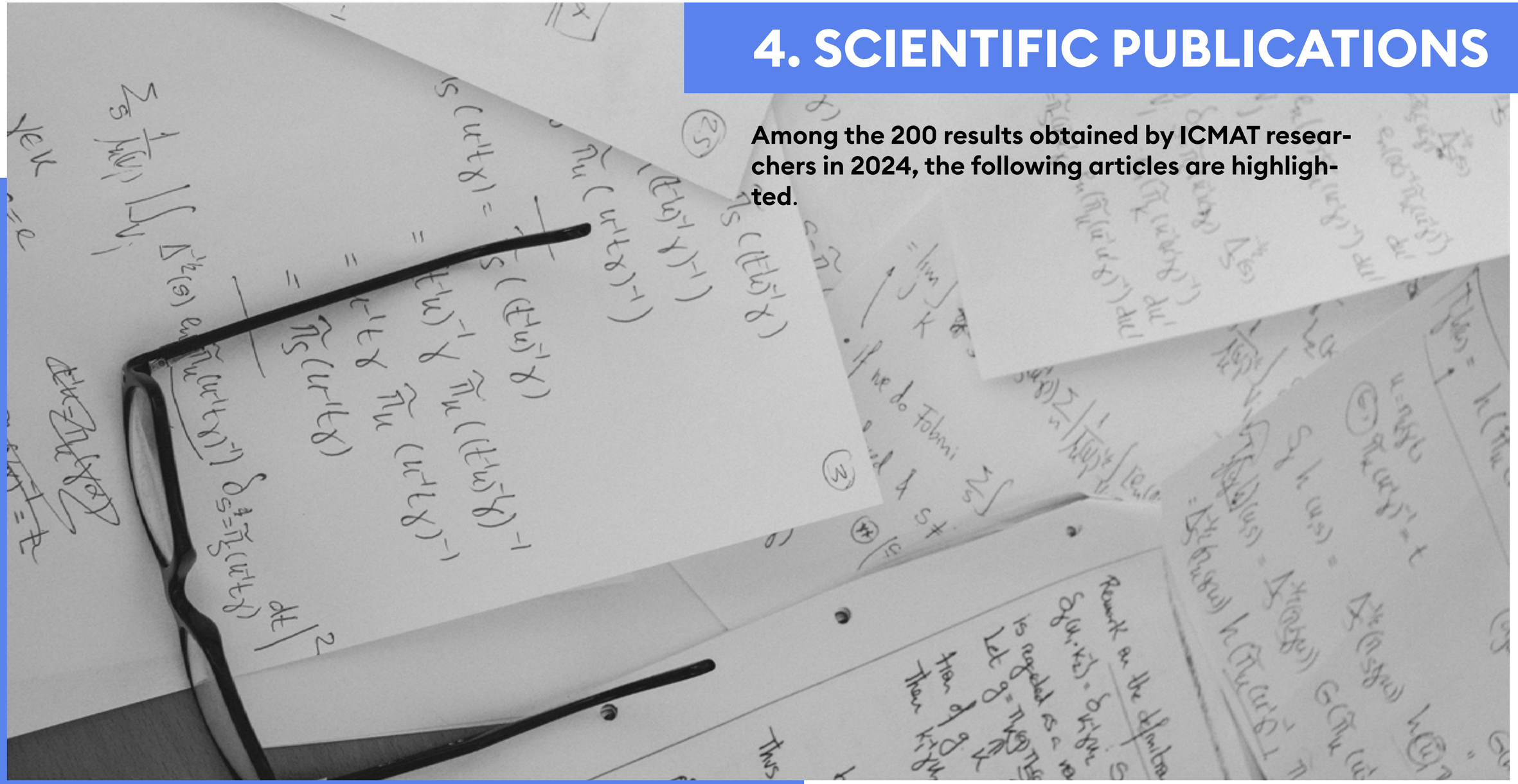
Claire Voisin (CNRS)

Frances Kirwan (University of Oxford)



Shing-Tung Yau (Tsinghua Univer-sity and Harvard University)

4. SCIENTIFIC PUBLICATIONS



Among the 200 results obtained by ICMAT researchers in 2024, the following articles are highlighted.

Off-diagonal estimates for the helical maximal function

Authors: David Beltran (University of Valencia), Jennifer Duncan (Autonomous University of Madrid) and Jonathan Hickman (University of Edinburgh)
Source: Proceedings of the London Mathematical Society, Volume 128, Issue4 e12594

Date of Publication: April 2024.

Link

Review: Harmonic analysis has had, since the introduction of the spherical maximal function by Stein in the '70s, an abiding interest in variants on the Hardy-Littlewood maximal function that involve taking averages along lower-dimensional sets, in no small part due to their delicate nature and their connection with dispersive PDE. Interestingly, the spherical maximal function turns out to be much harder to prove in two dimensions (wherein it is referred to as the 'circular' maximal function) than in higher dimensions, and many new unexpected geometric features start to play a role in its behaviour. Lebesgue estimates on the circular maximal function were eventually proved by Bougain in the '80s, and in following decades the helical maximal function has come to be viewed as the appropriate higher dimensional analogue of the circular maximal function problem, in that it lifts the geometric subtleties of the problem into higher-dimensions in a way that the spherical maximal function does not.
The optimal diagonal Lebesgue estimates for the helical maximal function in three dimensions were proved independently by Beltran-Guo-Hickman-Seeger and Ko-Lee-Oh via methods that centred around distinct features of the problem. By developing a methodology that incorporates both geometries, David Beltran (University of Valencia), Jennifer Duncan (Autonomous University of Madrid) and Jonathan Hickman (University of Edinburgh) were able to establish the full conjectured off-diagonal range except for certain endpoints. Both the on- and off-diagonal problems remain open in higher dimensions.

Rings of Siegel–Jacobi forms of bounded relative index are not finitely generated

Authors: Ana María Botero (University of Regensburg, Germany, at the time of the work, now at the University of Bielefeld, Germany), José Ignacio Burgos Gil (ICMAT-CSIC), David Holmes (Mathematical Institute, Leiden University) and Robin de Jong (Mathematical Institute, Leiden University)
Source: Duke Mathematical Journal, 173(12): 2315–2396 (1 September 2024). DOI: 10.1215/00127094-2023-0059

Date of Publication: September 202

Link

Review: In science, no law is immutable. All laws must be continuously tested against reality, and if an experiment shows that a law is inaccurate, it is replaced by another. In mathematics, however, we have proofs. If a result is proven, it is considered set in stone and immutable. However, the complexity of modern mathematics often makes it impossible to rigorously verify all results during peer review, and errors can appear in various publications. These errors are typically not discovered by reading the proofs, but because their consequences contradict other established results.
The origin of this article is a result published more than 30 years ago that seemed too good to be true. Siegel–Jacobi, a generalisation of the modular forms, including theta functions functions, and are of great importance in the study of abelian varieties and families of abelian varieties. Just as classical modular forms are classified by a single number, the weight, Siegel–Jacobi forms are classified by two numbers: the weight and the index. One of the classical problems in the theory is the calculation of the dimension of the space of Siegel–Jacobi forms with a given weight and index. A result by Runge, published in the 1990s, states that the ring of Siegel–Jacobi forms with a fixed ratio between weight and index is finitely generated. This would imply that the dimensions of Siegel–Jacobi forms should be relatively easy to calculate–somewhat like counting the number of lattice integers contained within the multiples of a polyhedron with rational vertices. In contrast, the problem of determining the dimension of the Siegel–Jacobi forms is more complex and resembles counting the number of lattice integers within the multiples of a curved convex shape.
In this article, the authors use the theory of b-divisors on toroidal varieties to prove that the ring of Siegel–Jacobi forms with a fixed and positive ratio between weight and index is never finitely generated. As an application of these techniques, they prove a conjecture of Kramer regarding the interpretation of Siegel–Jacobi forms as global sections of certain fiber bundles and provide a new proof of a formula by Tai concerning the asymptotic behavior of the dimension of the Siegel–Jacobi forms.

A general Cayley correspondence and higher rank Teichmüller spaces

Authors: Steven Bradlow (University of Illinois at Urbana-Champaign), Brian Collier (University of California Riverside), Oscar García-Prada (ICMAT), Peter B. Gothen (University of Porto) and André Oliveira (University of Trás-os-Montes e Alto Douro)
Source: Annals of Mathematics Volume 200 (2024), Issue 3, pages 803-892.

Date of Publication: November 2024.

Link

Review: It is well-known that the Teichmüller space of a compact surface can be identified with a connected component of the moduli space of representations of the fundamental group of the surface in PSL(2, $\mathbb{R}$). Higher rank Teichmüller spaces are generalizations of this that exist in the moduli space of representations of the fundamental group into certain simple real non-compact Lie groups of higher rank. As with the usual Teichmüller space, these spaces consist entirely of discrete and faithful representations.
The first instances of such higher rank Teichmüller spaces were provided by Hitchin in his seminal paper "Lie groups and Teichmüller space", using the theory of Higgs bundles that he had introduced earlier in 1987. A subsequent class of higher rank Teichmüller spaces was given by the maximal Toledo invariant representations in groups of Hermitian type. The Higgs bundle construction of these for general groups of Hermitian type was given by Biquard–García-Prada–Rubio in the paper "Higgs bundles, Toledo invariant and the Cayley correspondence", after several constructions by Bradlow, García-Prada, Gothen, and Mundet i Riera for classical groups. The combination of the theory of Higgs bundles with work by Labourie on Anosov representations and Burger–Iozzi–Wienhard provided the main tools to conclude that all representations in these components were discrete and faithful.
For some time, it was believed that split real groups and groups of Hermitian type were the only two classes of groups for which higher rank Teichmüller spaces existed. However, again the theory of Higgs bundles, and work by Guichard–Wienhard on positive structures on Lie groups, generalizing Lusztig positivity for split groups, indicated that this was not the case. A Higgs bundle construction for the family of groups SO(p, q) was given in the paper by M. Aparicio-Arroyo, S.B. Bradlow, B. Collier, O. García-Prada, P.B. Gothen, and A. Oliveira, SO(p, q)-Higgs bundles and higher Teichmüller components, Inventiones Mathematicae, 218 (2019), 197–299.
In the paper under review, the authors give a general Higgs bundle classification and unified construction of higher rank Teichmüller spaces. In addition to recovering the cases mentioned above, they identify new groups for which higher rank Teichmüller spaces exist. The groups in question are quaternionic real forms of the exceptional groups F4, E6, E7, and E8. An important tool for this construction is the introduction and classification of a special class of sl2-triples of a simple complex Lie algebra, that they call magical. Each situation appears by means of a Cayley-type correspondence for a different choice of magical triple. The classification of magical triples matches completely the classification of positive structures by Guichard–Wienhard, which plays a central role in the characterization of the higher rank Teichmüller spaces.

On refined conjectures of Birch and Swinnerton-Dyer type for Hasse–Weil–Artin L-Series

Authors: David Burns (King's College London) and Daniel Macias Castillo (ICMAT-CSIC)
Source: Memoirs of the American Mathematical Society Vol. 297, Num. 1482, 2024, 156 pp.

Date of Publication: May 2024.

Link

Review: Let A be an abelian variety defined over a number field k. By a celebrated theorem of Mordell and Weil, the abelian group that is formed by the set of points of A with coefficients in k is finitely generated. It is also conjectured that the Hasse-Weil L-series L(A,z) of A has a meromorphic continuation to the entire complex plane and satisfies a functional equation with central point z=1 and, in addition, that the Tate–Shafarevich group of A is finite. Assuming these conjectures to be true, the Birch and Swinnerton-Dyer conjecture ('BSD') predicts an explicit formula that relates the leading coefficient in the Taylor expansion of L(A,z) at z=1 to several key algebraic invariants of A, including the order of its Tate-Shafarevich group.
This remarkable prediction is regarded as one of the most important problems in arithmetic geometry. Nevertheless, there are various natural contexts in which it does not encompass the full extent of the interplay between the analytic and algebraic invariants of A. In particular, 'refined conjectures of BSD type' have been formulated and studied by several authors including Bertolini, Darmon, Deligne, Gross, Kato, Kurihara, Mazur, Rotger, Rubin

and Tate.
In this article the authors formulate a seemingly definitive refinement of the BSD conjecture for the Hasse-Weil-Artin L-series associated to A and to finite dimensional complex characters of the absolute Galois group of k. They then derive a range of concrete consequences of this conjecture that are amenable to explicit investigation. In particular, they show that their conjecture both refines and extends the existing theory of refined conjectures of BSD type, and also implies the relevant case of the Equivariant Tamagawa Number Conjecture ('ETNC').
In important special cases they provide strong evidence for the validity of our conjecture. For instance, in the setting of rational elliptic curves and of characters that factor through number fields that are both abelian and tamely ramified, they use the theory of modular symbols and a theorem of Kato to obtain a proof of their conjecture for very general families of such curves and characters. This result also extends the previous verifications of the ETNC in this setting. In certain more difficult settings, they are also able to provide numerical verifications of their conjecture.
In the words of one of the anonymous referees, the article constitutes an arguably definitive treatment of several topics in the arithmetic of abelian varieties.

Carleson measure estimates, corona decompositions, and perturbation of elliptic operators without connectivity

Authors: Mingming Cao (ICMAT-CSIC), Pablo Hidalgo-Palencia (ICMAT-CSIC) and José María Martell (ICMAT-CSIC)
Source: Mathematische Annalen Volume 390, 95–156 (2024)

Date of Publication: 2024.

Link

Review: In 1977, Dahlberg showed that the Dirichlet problem can be solved in L^2 in any Lipschitz domain. Since then there has been an intense research devoted to finding appropriate conditions under which one can solve the Dirichlet problem with data in Lebesgue spaces. After many deep partial results, recently, a complete answer for the Dirichlet problem with boundary data in L^p for finite p spaces was given by Azzam, Hofmann, Martell, Mourgoglou and Tolsa, (2020). They characterized the domains on which this problem is solvable in terms of two properties. The firs one that is related to the "regularity" of the boundary, namely the the uniform rectifiability of the boundary (basically, it contains many Lipschitz pieces). The second is linked to the connectivity of the domain, more precisely the existence of non-tangential accessibility paths connecting the interior of the the domain to some fixed portion of the boundary. This characterization only applies to the Laplace equation, and it is known (counterexamples were found in the 80s) that the same characterization cannot hold for just any operator in divergence form with bounded coefficients. Nevertheless, a deep result of [Fefferman, Kenig, Pipher, 1991] gave hope that such characterization could be true for a (rather wide) class of operators.
In the present work, the authors give the first steps towards extending the characterization of Azzam, Hofmann, Martell, Mourgoglou and Tolsa, (2020) to the class of operators described by Fefferman, Kenig and Pipher (1991). Indeed, they establish an abstract perturbation theory that allows them to modify the operator while maintaining properties which are very closely tied to the well-posedness of the Dirichlet problem with data in L^p for finite p. As a consequence, they prove, for a subclass of the so-called Kenig-Pipher operators, that the solvability of such Dirichlet problems is only possible in uniformly rectifiable sets. The main novelty of the work is that this perturbation theory is true without the need of any background strong connectivity assumption: indeed, working without strong connectivity is the key in Azzam, Hofmann, Martell, Mourgoglou and Tolsa (2020), so their steps towards working without connectivity may pave the way towards the full extension of that work beyond the Laplace equation.
On the technical side, to properly remove all connectivity assumptions and, at the same work with operators which are much more poorly behaved than the Laplacian, they need to define new properties that encapsulate the fact that there may be scales where things go wrong. For instance, they may expect the Green's function to behave linearly around some parts of the boundary, but definitely not all of them (as is expected in settings with connectivity). Using appropriate dyadic structures, Carleson measures and corona decompositions, they are able to disregard the regions where the behaviour is not the expected one, and still obtain the desired global properties.

Instantaneous gap loss of Sobolev regularity for the 2d incompressible Euler equations

Authors: Diego Córdoba (ICMAT-CSIC), Luis Martínez-Zoroa (ICMAT-CSIC) and WOJCIECH S. OŻAŃSKI (Florida State University)
Source: Duke Mathematical Journal 173 (2024), no. 10, 1931–1971.

Date of Publication: July 2024.

Link

Review: The main result in this paper is to construct unique global classical solutions of the 2D incompressible Euler equations with finite energy that have an instantaneous gap loss of supercritical Sobolev norms. More precisely, the authors construct unique solutions of the 2D incompressible Euler equations (in vorticity formulation) in R^2 ×[0, ∞) with initial vorticity in the super-critical Sobolev space H^β , 0 < β < 1, which, at each time t > 0, does not belong to any H^β ′ , where β ′ > (2 − β)β/ (2 − β^2) .
The proof relies on a new method called pseudo-solutions, which allows one to track the evolution of a solution to the equation for t>0, given a family of initial data. This method becomes more effective with increasingly oscillatory initial data. For instance, initial data with high oscillations and high concentration provide better control over the error between the pseudo-solution and the actual solution of the PDE. In contrast, classical methods for studying local well-posedness lose effectiveness as the oscillations in the initial data grow. The method of pseudo-solutions compensates for this limitation by identifying the leading-order behavior of the solution responsible for the loss of control. By explicitly (or nearly explicitly) tracing this behavior, the main effort reduces to estimating the approximation error. Naturally, the more carefully chosen the pseudo-solution, the easier it becomes to control these errors.
This advantage is evident in the analysis of the 2D Euler equations, where new analytic tools provide strong control over the oscillations in the angular variable, particularly between the inner and outer components of the pseudo-solution. However, in the case of the Euler equations, obtaining lower bounds for the H^β-norm of the pseudo-solution (or the exact solution) is challenging but necessary to demonstrate the growth of this norm over time. To address this, the authors estimate homogeneous Sobolev norms of negative order for the pseudo-solution from above and apply interpolation techniques to derive the required lower bounds. These advancements have enabled them to demonstrate a “gap loss” in Sobolev regularity, rather than merely establishing strong ill-posedness. This result is a novel contribution to the study of incompressible fluid mechanics.

Non-integrability and chaos for natural Hamiltonian systems with a random potential

Authors: Alberto Enciso (ICMAT-CSIC), Daniel Peralta-Salas (ICMAT-CSIC) and Alvaro Romaniega (ICMAT-CSIC).
Source: Advances in Mathematics vol 437, 109448.

Date of Publication: February 2024.

Link

Review: Consider the ensemble of Gaussian random potentials {V^L(q)}_{L=1}^\infty on the d-dimensional torus where, essentially, V^L(q) is a real-valued trigonometric polynomial of degree L whose coefficients are independent standard normal variables. The main result of this paper ensures that, with a probability tending to 1 as L\ to\infty, the dynamical system associated with the natural Hamiltonian function defined by this random potential, H^L:=1/2|p|^2+V^L(q), exhibits a number of chaotic regions which coexist with a positive-volume set of invariant tori. In particular, these systems are typically neither integrable with non-degenerate first integrals nor ergodic. An analogous result for random natural Hamiltonian systems defined on the cotangent bundle of an arbitrary compact Riemannian manifold is presented too.

Magnetic helicity, weak solutions and relaxation of ideal MHD

Authors: Daniel Faraco (ICMAT-UAM), Sauli Lindberg (University of Helsinki) and László Székelyhidi Jr. (Max Planck Institute for Mathematics in the Sciences)
Source: Communications on Pure and Applied Mathematics Volume77, Issue4, Pages 2387-2412.

Date of Publication: April 2024.

Link

Review: The equations of magnetohidrodynamics describe the evolution of the magnetic and the velocity fields in a magnetised fluids at non relativistic velocities. If the magnetic field vanishes, we recover the Euler

equations. It is easy to see that smooth solutions of ideal MHD preserve energy but there are are another invariants (Casimirs), namely cross helicity and more importantly magnetic helicity. Since the 1950 magnetic helicity is expected to be more robust than energy and it is expected to be conserved even in turbulent regimes that is the Taylor conjecture. Recently Beckie, Bukcmaster and Vicol prove that there are square integrable solutions which do not preserve magentic helicity and it is known that solutions such that if the velocity and the magnetic field have spatial cubic integrability the helicity is preserved. In a recent review it was asked whether there exist solutions which dissipate magnetic helicity with integrability all the way below the cubic integrability and whether one could construct solutions exhibiting anomalous dissipation of energy but conserving arbitrary magnetic helicity. In this paper the authors solved both conjectures.

Gauge theory for string algebroids

Authors: Mario Garcia-Fernandez (ICMAT-CSIC), Roberto Rubio (Universidad Autónoma de Barcelona) and Carl Tipler (Université de Bretagne Occidentale)
Source: Journal of Differential Geometry 128(1): 77-152. DOI: 10.4310/jdg/1721075260

Date of Publication: September 2024.

Link

Review: Back to the work of Atiyah and Bott (1983), the interaction of mathematical gauge theories with symplectic geometry and, in particular, the idea of Hamiltonian reduction, has had an important impact in our understanding of moduli theory in algebraic geometry. The main result revolving this idea is the Donaldson-Uhlenbeck-Yau Theorem, initially conjectured by Hitchin and Kobayashi, which establishes a correspondence between the moduli space of solutions of the gauge theoretical Hermite-Yang-Mills equations and the moduli space of bundles on a compact Kähler manifold, satisfying a suitable numerical condition called “stability”. A key upshot of this important result is that certain moduli spaces in algebraic geometry, constructed via Mumford’s Geometric Invariant Theory, are endowed with natural Kähler metrics.
In a publication in the Journal of Differential Geometry, Mario Garcia-Fernandez (ICMAT), Roberto Rubio (UAB) and Carl Tipler (Université de Bretagne Occidentale) explore a new scenario where the Hamiltonian reduction picture arises. For this, the authors consider a class of holomorphic bundle-like objects which have appeared very recently in higher gauge theory. In this setup, the structure group of the bundle is replaced by a mild category, dubbed as complex Lie 2-group (2023). The authors go on to apply their construction to the moduli theory for the Hull-Strominger System. This system of partial differential equations has its origins in string theory (1986) and was first studied in mathematics by Shing-Tung Yau (Tsinghua) and Jun Li (Stanford) (2005), having an important impact in complex geometry ever since. The main results of the manuscript are concerned with the geometry of the moduli space of solutions for these equations. Under natural hypothesis, the authors prove that the moduli space carries a pseudo-Kähler metric with an explicit formula for the Kähler potential, a cohomological formula for the metric, and an infinitesimal version of the Donaldson-Uhlenbeck-Yau theorem.

Free Q-groups are residually torsion-free nilpotent

Authors: Andrei Jaikin-Zapirain (UAM-ICMAT)
Source: Annales Scientifiques de l’École Normale Supérieure 57 (2024), 1101-1133

Date of Publication: 2024.

Link

Review: Let F(x, y) be the free group on two generators x and y, and let A(a, b) = Q << a, b >> denote the ring of formal non-commutative power series in two variables a and b. A classical result of Wilhelm Magnus states that the map sending x to 1 + a and y to 1 + b defines an embedding of F(x, y) into the multiplicative group A(a, b)^*. This embedding, known as the Magnus representation, has played a fundamental role in combinatorial group theory.
In his doctoral thesis, Gilbert Baumslag initiated the study of Q-groups, which are groups in which every element has a unique nth root for all natural numbers n. He introduced the notion of a free Q-group, denoted F^Q(x, y), and proved that the Magnus representation extends naturally to a homomorphism:
F^Q(x, y) → A(a, b)^*.
A central question posed by Baumslag was whether this extended homomorphism remains injective.
The paper provides a positive answer to Baumslag’s question by proving the injectivity of this homomorphism. In fact, this result is proved in the more general context of free A-rings for binomial domains A.

Virtually free-by-cyclic groups

Authors: Dawid Kielak (University of Oxford) and Marco Linton (ICMAT-CSIC)
Source: Geometric and Functional Analysis (GAFA) Volume 34, pages 1580–1608, (2024)
Date of Publication: July 2024.
Link
Review: A group is free-by-cyclic if it admits a surjection onto the integers with kernel a free group. The class of (finitely generated free)-by-cyclic groups has been the focus of intense research in the last few decades which has resulted in a beautiful theory that combines ideas from algebra, geometry and dynamics. In this article the authors contribute to this theory by developing a homological criterion for when a group is virtually a subgroup of a (finitely generated free)-by-cyclic group. The assumptions they need for their method are geometric in nature and satisfied by generic groups, and their characterisation is given in terms of the cohomological dimension and the second L^2 -Betti number, two invariants that are generally easy to compute. Their main application is a solution to a conjecture of Baumslag's from 1986: every one-relator group with torsion has a finite index subgroup that is free-by-cyclic. More generally, they use their criterion to show that a surprisingly large class of previously studied groups turn out to be virtually free-by-cyclic. In particular, they show that all known coherent hyperbolic groups of cohomological dimension two are actually virtually free-by-cyclic.

Books

ICMAT researchers published the following books during 2024:

Córdoba Barba, Antonio, *Suprematism in Harmonic Analysis*, Birkhäuser Cham, Progress in Mathematics series (PM, volume 356).

Abstract: This award-winning monograph explores advanced topics in harmonic analysis, addressing both classical and contemporary problems. Several connections to number theory, crystallography or atomic theory are also surveyed. The term “suprematism” refers to a certain geometric point of view underlying proofs and arguments.
With a focus on rigorous research insights for graduate students and researchers in mathematics, this book provides a comprehensive journey through the hidden landscapes of harmonic analysis.

G. Arce, Pablo and Ríos Insua, David, *Adversarial Machine Learning*, Wiley StatsRef: Statistics Reference Online (eds N. Balakrishnan, T. Colton, B. Everitt, W. Piegorsch, F. Ruggeri and J.L. Teugels).

Abstract: This paper introduces key concepts in adversarial machine learning (ML). Its aim is to deliver ML approaches that are more robust against adversarial attempts to alter their performance. We cover the cases of classification, regression, unsupervised, and reinforcement learning. The three core topics in the field (attacks, defenses, and workflows) are briefly discussed.

Image: Ministerio de Ciencia, Innovación y Universidades

5. SEVERO OCHOA PROGRAMME

In April 2024, and for the fourth consecutive time, ICMAT received the Severo Ochoa seal of excellence from the Ministry of Science, Innovation and Universities. The announcement of the 2024 program resolution, made by Spain's Minister of Science, Innovation, and Universities, Diana Morant, took place at ICMAT in July.

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

This accreditation is endowed with €4.5 million in funding secured until 2028, the Institute will strengthen its institutional structure. Additionally, €1.6 million will be allocated to the training of research personnel, reinforcing ICMAT's commitment to nurturing new talent.

Since October 2017, ICMAT has been part of the Alliance between the Severo Ochoa Centres and the María de Maeztu Units, known as SOMMa, which brings together more than 50 leading Spanish research institutions with more than 8,500 researchers. Since 2023 ICMAT has a seat on its Executive Committee.

As in previous years, a significant portion of this year's funding has been dedicated to staff recruitment, including management experts and pre- and post-doctoral researchers, whose contributions are essential to the success of ICMAT's excellence program. This funding also supported a substantial part of ICMAT's scientific activities, which included approximately 30 conferences and workshops, 30 colloquia, 15 courses, three schools, a thematic research program, and over 100 seminars. Additionally, it covered part of the expenses for the 800 visitors who participated in these events. Moreover, the funding facilitated research visits by ICMAT researchers and enabled more than 150 students–including master's students and final-year students from the JAE School, representing institutions across Spain–to attend ICMAT events and undertake research stays with ICMAT members. Further allocations covered dissemination and communication initiatives at the Centre, expenses related to the Institute's gender plan, as well as costs for consumables, IT equipment, training for Centre members, and representation expenses.

Among the projects set to benefit from this funding, it is worth highlighting the continuation of the Distinguished Professors and Laboratories Programme.

Severo Ochoa Distinguished Visiting Professors and Laboratories 2024-2028

After three editions, the programme has proven to be a resounding success. Its impact can be seen both in the quality and quantity of scientific output and in the establishment of strong links with prestigious institutions. The activities generated by each of these groups will serve to attract a large number of visitors to the Institute, strengthen the scientific cohesion of our research groups and reinforce ICMAT's position as an indisputable point of reference within the international mathematical community. The initiative has associated funding for scientific activities, for the development of thematic programmes and for contracts for pre-doctoral and post-doctoral researchers, offering high quality training in our country.
The 2024-2028 Severo Ochoa Distinguished Visiting Professors and Laboratories Programme will be led by 14 internationally renowned researchers:

Distinguished Visiting Professor: Bruno Anglès

Bruno Anglès, Professor at the Université de Caen Normandie (France), is an expert in number theory and special functions. His work focuses on L-functions and the relations between number theory and Galois theory. He has been recognised for his contributions at the intersection of arithmetic and algebraic geometry.
As a Distinguished Visiting Professor (PVD), Anglès works, together with his collaborators at ICMAT, in the areas of arithmetic geometry and algebraic number theory. More specifically, in the arithmetic of global bodies of functions, bodies of rational functions on algebraic curves defined on finite bodies.

Coordinator: Daniel Macías, CSIC researcher at ICMAT.

Martin Bridson – Alan Reid Laboratory

Alan Reid, currently a professor at Rice University (USA), works in geometric group theory, hyperbolic geometry and the topology of varieties in three dimensions, areas in which he has achieved highly influential results.
Martin Bridson, professor at University of Oxford (UK), is also director of the Clay Institute of Mathematics, an institution dedicated to the funding and promotion of mathematics – among its programmes is the list of Millennium Problems, whose resolutions are rewarded with a million dollars. His fields of specialisation are low-dimensional topology, geometric group theory and spaces of non-positive curvature. Among other distinctions, he has received the LMS Whitehead Prize (1999), the Wolfson Prize for Merit in Research from the Royal Society (2012), and the Steele Prize from the American Mathematical Society (2020).
The Bridson-Reid Laboratory works in the area of geometric group theory, where groups are studied from a geometric perspective, using tools and concepts from geometry and topology to understand the structure and properties of groups.

Coordinator: Andrei Jaikin, professor at the Universidad Autónoma de Madrid and member of ICMAT.

Distinguished Visiting Professor: Elena Celledoni

Elena Celledoni is a professor at Norges teknisk-naturvitenskapelige Universitet (Norwegian University of Science and Technology). Her main field of research is computational mathematics, with a focus on numerical methods for differential problems and geometric integration. Celledoni has worked extensively on techniques for accurate and efficient numerical simulation, particularly in mechanics and physics.
Celledoni joins ICMAT as a PVD. The collaboration will focus on the areas of geometric integration and neural network analysis using differential geometry methods. The main objective is to obtain important results in geometric methods, both for continuous and discrete dynamical systems.

Coordinator: David Martín de Diego, CSIC research scientist at ICMAT.

Ignacio Cirac Laboratory

Ignacio Cirac is director of the Max Planck Institute for Quantum Optics (Germany). A pioneer in the field of quantum information and quantum computing, his proposal of the first schemes for quantum computing based on ion traps has received international recognition. He has received numerous awards, including the Prince of Asturias Award for Technical and Scientific Research in 2006, the BBVA Frontiers of Knowledge Award (2008), the Benjamin Franklin Medal (2010), the Wolf Prize in Physics (2013) and the Max-Planck Medal (2018).
The Ignacio Cirac Laboratory, as a continuation of the previous one, will continue to focus on the development and implementation of quantum technologies, one of the main technological challenges of today. In addition, the group hopes to initiate new lines of work, such as, for example, connecting the theory of tensor networks with areas and techniques of computer science.

Coordinator: David Pérez García, professor at the Complutense University of Madrid and member of ICMAT.

Charles Fefferman Laboratory

Charles Fefferman, professor at Princeton University, Princeton University (USA), was awarded the Fields Medal in 1978 for his work on problems of analysis in several complex variables and partial differential equations. His research has had a major impact in many other fields: Fourier analysis, mathematical physics, fluid dynamics, neural networks and differential geometry.
The Charles Fefferman Laboratory is once again focused on solving problems in fluid mechanics, and in particular the well-known Navier-Stokes problem, one of the most important problems in mathematics and physics, which has remained open for more than 250 years. It consists of the possible formation of singularities in the solutions to the set of non-linear partial differential equations – the Navier-Stokes equations – that describe the motion of fluids.

Coordinator: Diego Córdoba, CSIC research professor at ICMAT.

Nigel Hitchin and Ngô Bảo Châu Laboratory

Nigel Hitchin is Emeritus Professor at the University of Oxford (UK). Hitchin is recognised for his contributions to differential geometry and gauge theory, including the development of the Hitchin equations and their applications to surface geometry and string theory. He was awarded the Shaw Prize in 2016 for his work in geometry and topology. He has also received the Whitehead Prize (1980), the Berwick Prize (1990) and the Polya Prize (2002), as well as the Sylvester Medal of the Royal Society (2000).
Ngô Bảo Châu, currently a professor at the University of Chicago (USA), is an expert in number theory and algebraic geometry. He is known for his proof of the Fundamental Lemma in the Langlands programme, which earned him the Fields Medal in 2010. He has also been awarded the Clay Research Prize (2004), the Sophie Germain Prize (2007), the Oberwolfach Prize (2007) and the Légion d'honneur (2011).
The Nigel Hitchin – Ngô Bảu Châu Laboratory will continue to focus on various areas of algebraic geometry and mathematical physics: Hitchin system, Langlands duality, mirror symmetry, Higgs bundles, character varieties and higher Teichmüller spaces, gauge theories, moduli spaces and geometric structures.

Coordinator: Oscar García-Prada, CSIC research professor at ICMAT.

Distinguished Visiting Professor: Monika Ludwig

Monika Ludwig is a professor at the Technische Universität Wien (Vienna, Austria). Her field of specialisation is geometric measure theory and convexity theory. Ludwig has made significant contributions to convex body theory, including research on valuation functions and shadow bodies. She has been a visiting professor at several renowned universities in Europe and North America.
Ludwig's joining this programme as a PVD will be instrumental in advancing the geometric theory of valuations, both in the Brunn-Minkowski context and in its dual. This theory is encompassed in metric geometry, an area that lies at the intersection of geometry, analysis and convexity.

Coordinator: Pedro Tradacete, CSIC scientist at ICMAT.

Distinguished Visiting Professors: Eugenia Malinnikova and Eero Saksman

Eugenia Malinnikova is a professor at Stanford University (USA). Her research focuses on harmonic analysis, partial differential equations and spectral theory. She has received several awards, including the 2017 Clay Research Fellowship Award for her work in spectral theory and harmonic analysis.
Eero Saksman is a professor at the Helsingin yliopisto (University of Helsinki, Finland). His research covers areas such as stochastic analysis, martingale theory and spectral theory, geometric function theory and operator and probability theory.
As PVD, Malinnikova and Saksman will work at ICMAT in the fields of complex and harmonic analysis and potential theory.

Coordinator: Eva Gallardo, professor at the Complutense University of Madrid and member of ICMAT.

Distinguished Visiting Professor: Eva Miranda

Eva Miranda is a professor at the Universitat Politècnica de Catalunya (UPC). Her research focuses on geometry and topology, particularly in dynamical systems and symplectic geometry. Miranda has been a pioneer in the study of singularities in integrable systems and is recognised for her contributions to the topology of foliations and Poisson geometry.
Miranda's collaboration as a PVD at ICMAT is focused on the study of the level of complexity of the n-body problem in celestial mechanics. The specific objective is to find out whether it has a certain computational property: is it Turing complete, i.e. can it simulate any computational algorithm?

Coordinator: Daniel Peralta Salas, CSIC research scientist at ICMAT.

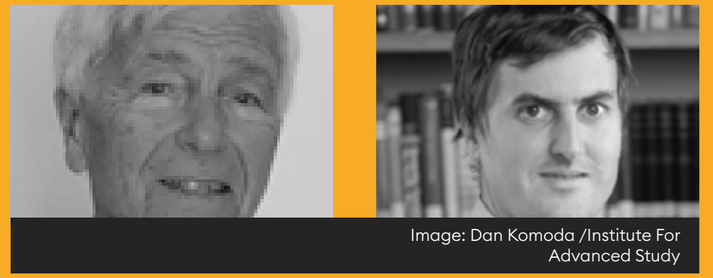


Image: Dan Komoda /Institute For Advanced Study

Gilles Pisier and Mikael de la Salle Laboratory

Gilles Pisier is Professor Emeritus at Texas A&M University (USA) and the Sorbonne-Institut de Jussieu University (France). His work in functional analysis, probability and operator algebras has earned him numerous honours and awards, including the prestigious Salem Prize in 1979 and the Ostrowski Prize in 1997. His research has influenced many areas of harmonic analysis, von Neumann algebras and the geometry of Banach spaces.
Mikael de la Salle is a professor at the Université de Lyon (France). His research interests include geometric group theory, geometry of Banach spaces and operator algebras. He has made decisive contributions on semisimple lattices of high rank and their associated von Neumann algebras, which have earned him several prizes, including the Société Mathématique de France prize.
The Pisier-de la Salle Laboratory will focus on the study of non-commutative Lp spaces from harmonic analysis, which also requires interaction with other fields, such as operator algebra and operator spaces, geometric group theory and quantum probability.

Coordinator: Javier Parcet, CSIC research scientist at ICMAT.

6. RESEARCH PROJECTS

ICMAT research staff lead research projects that receive funding from different national and international sources.

International Funding

European Funding

European Research Council Grants

Project	Code/Acronym	Reference	Principal Investigator	Start-final date
Non-local 3e in Incompressible Fluids	NONFLU	ERC- Advanced Grant 788250	Diego Córdoba	01/09/2018–301/08/2024
Quasiconformal Methods in Analysis and Applications	QUAMAP	ERC- Advanced Grant 834728	Kari Astala. ICMAT members: Daniel Faraco and Keith Rogers	01/09/2019-31/08/2025
Analysis of Geometry-Driven Phenomena in Fluid Mechanics, PDEs and Spectral Theory	FLUSPEC	ERC-Consolidator Grant 862341	Alberto Enciso	01/03/2021-28/02/2026

Societal Challenges Pillar

Project	Code/Acronym	Reference	Principal Investigator	Start-final date
A European “shield” against colorectal cancer based on novel, mor precise and affordable risk-based screening methods and viable policy pathways	ONCOSCREEN	101097036	David Ríos Insua	01/12/2022 - 30/11/2025

Marie-Sklodowska Curie actions

Project	Code/Acronym	Reference	Principal Investigator	Start-final date
Tracking the Time Evolution of Knots in Electromagnetism and Quantum Mechanics	KNOTDYNAPP	101023017	Daniel Peralta and Benjamin Bode	16/03/2022- 15/03/2024
Artificial Intelligence in Sustainable Development Goals (ALLIES)		101126626	David Ríos Insua (ICMAT)	01/01/2024 - 31/12/2028

Other International Funding

Project	Code/Acronym	Principal Investigator	Start-final date
Robust Command and Control under Adversarially Perturbed Data	FA8655-21-1-7042	David Ríos Insua	22/09/2021 - 21/09/2025

National Funding

Public Funding

Grants for research projects

Project	Code/Acronym	Principal Investigator	Start-final date
Centros de Excelencia Severo Ochoa	CEX2023-001347-S	Diego Córdoba Gazolaz	01/04/2024 - 31/03/2028
Apoyo a Centros de Excelencia Severo Ochoa	CEX2019-000904-S	Diego Córdoba Gazolaz	01/01/2020 - 31/03/2024
Dinámica de fluidos incompresibles	PID2020-114703GB-I00	Ángel Castro and Diego Córdoba	01/09/2021-28/02/2025
Análisis Matemático y Teoría de Información Cuántica	PID2020-113523GB-I00	Carlos Palazuelos and David Pérez	01/09/2021-31/08/2024
Métodos Profinitos y Analíticos en Teoría de Grupos	PID2020-114032GB-I00	Andrei Jaikin	01/09/2021-31/08/2025
Análisis armónico, combinatoria y aritmética	PID2020-113350GB-I00	Fernando Chamizo and Pablo Candela	01/09/2021-31/08/2024
Difusión no lineal: problemas locales y no locales	PID2020-116949GB-I00	Fernando Quirós Gracián	01/09/2021-31/08/2024
EDP no-lineales: difusión, geometría y aplicaciones	PID2020-113596GB-I00	María del Mar González	01/09/2021-31/08/2024

Project	Code/Acronym	Principal Investigator	Start-final date
Groupoids, von Neumann algebras and the mathematical foundations of Quantum Mechanics: Theory and applications	PID2020-117477GB-I00	Alberto Ibort	01/09/2021-31/08/2024
Methods and models for biomathematical applications	PID2020-112796RB-C21	Ana María Carpio	01/09/2021-31/08/2025
Espacios de Funciones y Técnicas de Acotación de Operadores en Análisis	PID2020-113048GB-I00	María Jesús Carro and Javier Soria	01/09/2021-31/08/2025
Aplicaciones del análisis funcional en problemas de geometría y teoría de la información	PID2020-116398GB-I00	Pedro Tradacete	01/09/2021 - 31/08/2025
Herramientas matemáticas para observación de la tierra	PID2021-123348OB-I00	Ana Mª Mancho	01/09/2022-31/08/2025
Un nuevo paradigma para el aprendizaje automático adversario	PID2021-124662OB-I00	David Ríos	01/09/2022-31/08/2025
Análisis de Fourier con aplicaciones a teoría de medida geométrica y problemas inversos	PID2021-124195NB-C33	Keith Rogers	01/09/2022-31/08/2025
Infinite groups from the algebraic, geometric, and combinatorial viewpoints	PID2021-126254NB-I00	Javier Aramayona	01/09/2022-31/08/2025

Project	Code/Acronym	Principal Investigator	Start-final date
Análisis variacional y geometría aplicada a problemas inversos y mecánica	PID2021-124195NB-C32	Daniel Faraco and Luis Guijarro	01/09/2022-31/08/2025
Ortogonalidad y aproximación con aplicaciones en machine learning y teoría de la probabilidad	PID2021-122154NB-I00	David Gómez-Ullate and Manuel Mañas	01/09/2022-31/08/2025
Hacia una economía circular: tecnología digital disruptiva como herramienta para la innovación en el diseño y desarrollo de fármacos (DIGIDREV)	TED2021-129970B-C21	Nuria Eugenia Campillo Martín and David Ríos Insua	01/12/2022-30/09/2025
Modelización y simulación de electrolisis alcalina en configuración de Zero Gap	TED2021-131530B-I00	Marco Antonio Fontelos López	01/12/2022-31/05/2025
GESDYSYHYS	PID2019-106715GB-C21	David Martín de Diego and Daniel Peralta	01/06/2023-29/02/2024
Red de Ecuaciones en Derivadas Parciales no Locales y Aplicaciones	RED2022-134463-T	Diego Córdoba Gazolaz	01/06/2023-31/05/2025
Aspectos geométricos de teoría espectral e hidrodinámica	PID2022-136795NB-I00	Daniel Peralta Salas and Alberto Enciso Carrasco	01/09/2023-31/08/2026
Geometría de sistemas dinámicos: de la teoría a las aplicaciones	PID2022-137909NB-C21	David Martin de Diego	01/09/2023-31/08/2027

Project	Code/Acronym	Principal Investigator	Start-final date
Geometría algebraica y aritmética	PID2022-138916NB-I00	Enrique González Jiménez and Orlando Villamayor	01/09/2023 - 31/08/2026
Fronteras del Análisis Armónico	PID2022-141354NB-I00	Javier Parcet Hernández and José María Martell Berrocal	01/09/2023-31/08/2027
Pares de Higgs, integrabilidad y métricas canónicas	PID2022-141387NB-C21	Oscar García Prada and Luis Álvarez Consul	01/09/2023-31/08/2026
Simetrías e Invariantes en Geometría y Aritmética	PID2022-142024NB-I00	José Ignacio Burgos Gil and Daniel Macías	01/09/2023-31/08/2027
Simetría espejo, álgebras de vértice y métricas canónicas	PID2022-141387NB-C22	Mario García Fernández	01/09/2023 - 31/8/2026
Simetría Espejo No-Kähler y Teoría de Gauge Superior	CNS2022-135784	Mario García Fernández	01/09/2023 - 31/08/2025
Teoria de Iwasawa no-conmutativa en característica positiva	CNS2023-145167	Daniel Macías Castillo	01/04/2024 - 30/06/2026
EMOROBCARE	IASOMM24002	David Ríos Insua and Juan Antonio Rodríguez Aguilar	04/06/2024 - 28/02/2026

Project	Code/Acronym	Principal Investigator	Start-final date
Sistema Remoto Integral de Monitorización, Detección y Predicción de Riesgos de Eventos Marinos Potencialmente Nocivos de Origen Natural o Antrópico en Áreas Off-Shore Destinadas a la Acuicultura	SIRENA	Ana Mª Mancho	22/07/2024 - 21/01/2026
Dinámica singular de fluidos incompresibles	PID2023-152878NB-I00	Diego Córdoba Gazolaz	01/09/2024 - 31/08/2027
Celestial mechanics, hydrodynamics and Turing machines	PCI2024-155062-2	Daniel Peralta Salas	01/11/2024 - 31/10/2027
Operator theory on free Banach spaces	PCI2024-155094-2	Pedro Tradacete	01/12/2024 - 30/11/2027
SECURe artificIAl intelligence (MOMENTUM)	MMT24-ICMAT-01	David Ríos Insua	20/12/2024 - 19/12/2028
Langrangian and Hamiltonian field theories - Geometry, discretization, optimal control	PCI2024-155047-2	David Martín	31/12/2024 - 30/12/2027
Mapping class groups from above and below	PCI2024-155037-2	Javier Aramayona	31/12/2024 - 30/12/2027
Topology of Moduli Hodge bundles, G-Higgs bundles and character varieties of surface groups	PCI2024-155103-2	Óscar García Prada	31/12/2024 - 30/12/2027

Grants to recruit scientific personnel

Call	Funding Entity	Number of grants in effect in 2024
Formación de Profesorado Universitario	Ministerio de Ciencia, Innovación y Universidades (MICIU)	2
Formación de Investigadores Predoctorales	Ministerio de Ciencia, Innovación y Universidades (MICIU)	20
Programa Doctorado Industrial	Comunidad Autónoma de Madrid	1
Programa INVESTIGO	Comunidad Autónoma de Madrid	1
Programa Momentum	Agencia Estatal Consejo Superior Investigaciones Cientificas (CSIC)	3

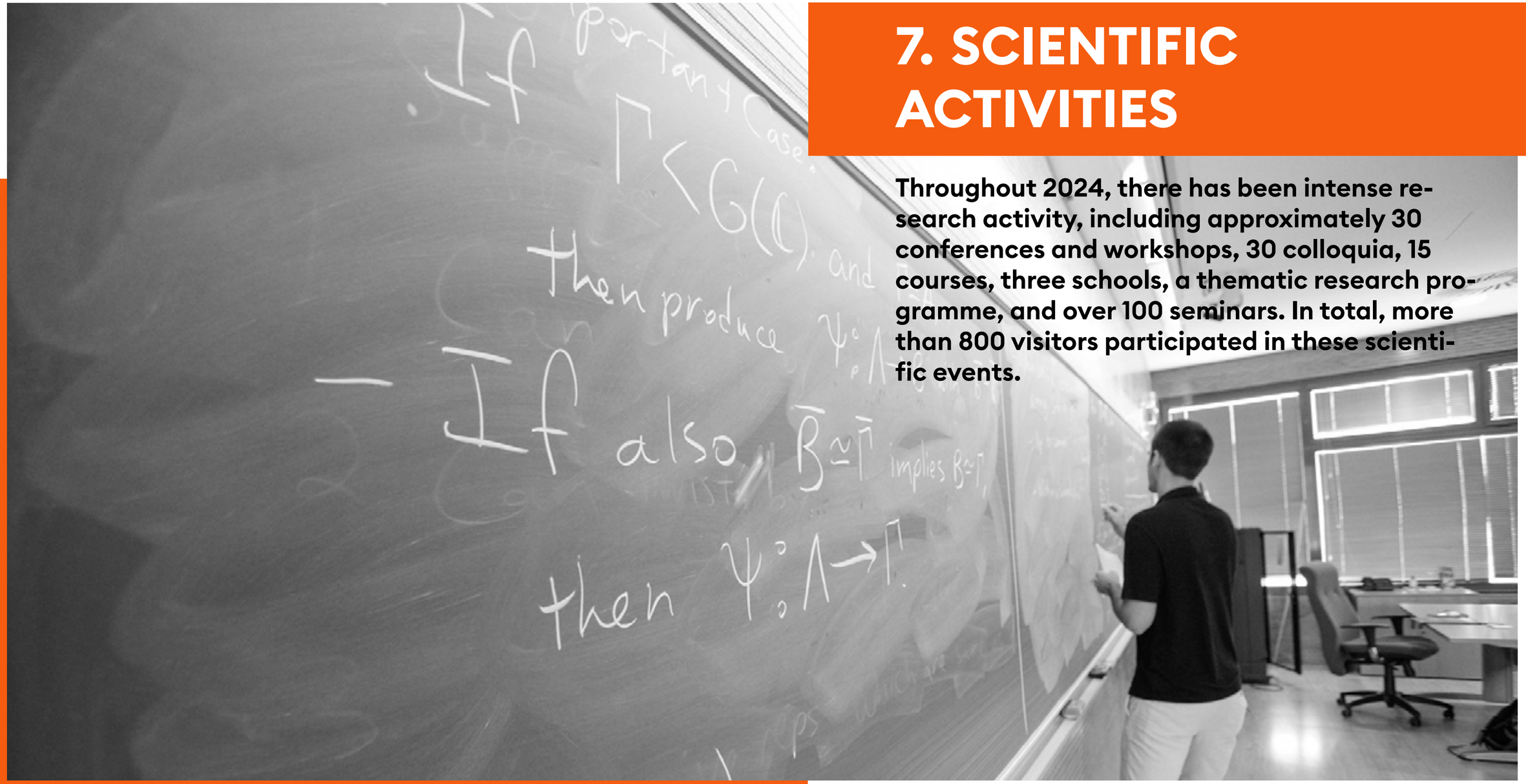
Private Funding

Grants for research projects

Project	Programme	Principal Investigator	Start-final date
Estructuras ordenadas en análisis, geometría y aplicaciones	Beca Leonardo 2022 BBVA Foundation	Pedro Tradacete	01/07/2023 - 30/06/2024
ZEREL DYNAMO	The Basement	David Ríos Insua	16/09/2023 - 31/05/2025
Instabilities in 2D incompressible fluids	Becas Leonardo 2023 BBVA Foundation	Ángel Castro	29/09/2023 - 29/05/2025
Development of a Training environment based on a reinforcement learning model in order to produce an intelligent training agent for Combat Aircraft pilots	Airbus Defence and Space SAU	David Ríos Insua	03/07/2024 - 02/06/2025
Desarrollo de funcionalidades de Intelligence Profiling usando analitíca predictiva avanzada	XEERPA MARKETING SOLUTIONS, SL	David Ríos Insua	01/10/2024 - 31/08/2025

Grants to recruit scientific personnel

Project	Programme	Beneficiary of the contract	Start-final date
Contributions to Adversarial Machine Learning	La Caixa Inphinit	José Manuel Camacho (PI: David Ríos)	16/01/2022 - 15/01/2025
Schwinger's picture of quantum mechanics and the foundations of classical and quantum field theories: Groupoids, algebroids and categories	La Caixa Inphinit	Arnau Mas (PI: Alberto Ibort)	01/10/2023 - 30/09/2026
Higgs bundles, big algebras and involutions	La Caixa Inphinit	Miguel González González (PI: Oscar García Prada)	01/11/2023 - 31/10/2026
Explicit approach to Galois representations of elliptic curves	La Caixa Inphinit	Jose A. Castro Moreno (PI: Nuno Barroso de Freitas)	01/10/2024-30/09/2028
Moduli spaces of geometric structures and stability	La Caixa Inphinit	Pablo Alberto Alvarado Seguel (PI: Luis Álvarez Cónsul)	16/12/2024-15/12/2028



7. SCIENTIFIC ACTIVITIES

Throughout 2024, there has been intense research activity, including approximately 30 conferences and workshops, 30 colloquia, 15 courses, three schools, a thematic research programme, and over 100 seminars. In total, more than 800 visitors participated in these scientific events.

Thematic Research Term: Lattice Structures in Analysis and Applications (LSAA)

1 April – 15 June

The research term brought together researchers interested in various aspects of lattice and ordered structures, with a particular emphasis on Functional Analysis and its applications. The topics covered included vector and Banach lattices, Banach spaces, operator theory, and phase retrieval, among others. The goal was to foster collaboration, especially among younger members of the community. It included the following actions:

Focus Week 1 - Phase Retrieval in Function Spaces (6-10 May)

Focus Week 2 - Vector Lattices and Ordered Structures (13-17 May)

Focus Week 3 - Interactions with Descriptive Set Theory (27-31 May)

Workshop Banach Spaces and Banach Lattices 20-24 May)

Mini-courses:

María Jesús Carro (Universidad Complutense de Madrid): Extrapolation in function spaces Extrapolation in function spaces (4 & 6 June)
Eugene Bilokopytov (University of Alberta): Introduction to order theory (13,14, 16 & 17 May)
Vladimir Troitsky (University of Alberta): Tensor products of vector lattices (14, 16 & 17 May)

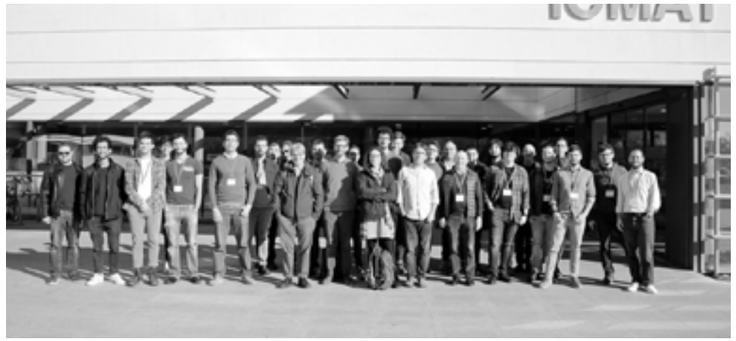
LSAA seminars:

David Muñoz-Lahoz (UAM-ICMAT): Inner band projections on BLAs (2 April)
Jesús Illescas (ICMAT): Kadec-Pelczysnki dichotomy interplay in phase retrieval (9 April)
Enrique García-Sánchez (ICMAT): In search of a functional representation of the free Banach lattice with upper p-estimates (16 April)
David de Hevia (ICMAT): Complemented Subspaces of Banach Lattices (23 April)
Jorge Santiago Ibáñez-Marcos (UCM - ICMAT): Valuations on Banach lattices (30 April)

Workhops

In 2024, ICMAT hosted an average of one international congress per month. These meetings bring together experts from all over the world to share the latest advances in the frontiers of current research. A workshop usually includes several talks, courses and other scientific meetings.

- Enhancing Mathematical Bridges between Spain and Latin America (24 April)
- Thematic Day on Fluid Mechanics (16 May)
- Quasiconformal Mappings, Elliptic Equations and Beyond (5-7 June)
- The Geometry of Field Theories (13-15 June)
- Décimas jornadas de teoría de números (8-12 July)
- Workshop on Geometrical Aspects of Material Modelling (21-23 August)
- Groups in Madrid 2024 (17-18 October)
- Reunión Red Temática de Geometría y Física (RTGF) (26-29 November)
- Postdocs day at ICMAT (3 December)
- Christmas M^3 Geometry Workshop (19-20 December)



Distinguished Lectures

Distinguished lectures are a series of talks given by leading figures of international standing in mathematics.

"Geometry of Brownian surfaces, I&II", Jean-François Le Gall (Université Paris-Saclay) (15 March)

Special colloquia

Special colloquia are lectures given by internationally recognised researchers in which they present a research topic to a broad mathematical community.

Image: IFT

Image: Luis Barta

"Theory of Atom", Ludmil Katzarkov (University of Miami, USA) (25 April)

"Rationality problems", Yuri Tschinkel (New York University, USA) (25 April)

"Algebraic and differential geometry: a 2-sided relationship", Nigel Hitchin (University of Oxford, UK) (25 April)

ICMAT-IFT Joint Colloquium: "Gravitational Waves and Binary Black Holes", Thibault Damour (Institut des Hautes Études Scientifiques, Bures-sur-Yvette, France) (7 May)

ICMAT-IFT Joint Colloquium: " Some new results on symmetries, conserved charges and black-hole physics », Tomás Ortín Miguel (Instituto de Física Teórica (IFT) (13 December)

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

The joint colloquia are bimonthly conferences organised on an itinerant basis at ICMAT, UAM, UCM and UC3M. They bring researchers in mathematics of international relevance to share their latest results with other mathematicians, not strictly specialists in their field.

"The Higher Infinite and its role in Mathematics", Joan Bagaria (Universitat de Barcelona & ICREA) (15 April)

"Analogies", Carlo Gasbarri (Université de Strasbourg) (24 May)

"The dynamical view on gradient invariants of groups", Clara Löh (Universität Regensburg) (31 May)

"Miraculous Integer Sequences", Motohico Mulase (University of California, Davis) (11 October)

"Spectral sets, weak tiling and Fuglede's conjecture", Máté Matolcsi, (Alfréd Rényi Institute of Mathematics) (12 November)

Schools

Research schools are intensive programmes that aim to provide an introduction to a current research topic for pre- and post-doctoral researchers in mathematics.

Summer School on h-principle (17-21 June)
XVI International ICMAT Summer School on Geometry, Dynamics and Field theory (20-25 June)
JAE School of Mathematics 2024 (24 June – 5 July)
Third AIHUB Summer School (01-05/07/2024) Organised by David Ríos Insua (ICMAT-CSIC), through AIHUB CSIC, co-organised with EduCaixa, Fundación "la Caixa", and Institut de Física Corpuscular (IFIC).

Courses

Courses are a series of sessions designed to introduce researchers to an advanced area of research.

A Brief Introduction to G2-Geometry, Andrés Julián Moreno Ospina (UNICAMP) (9 April & 16 April)
Concentration and blow-up via asymptotic gluing, Marco Badran (ETH Zürich) (7-8 May)
Teoría de cuerpos de clases y teoría K de Milnor, Oliver Braunling (ICMAT) (5-7 June)
Analytic, geometric, and topological methods for Sobolev mappings to manifolds, Antoine Detaille (Université de Lyon) (4, 7, 11 & 14 November)

Seminars

Seminars - one-hour meetings in which researchers share their own results - are held every week at ICMAT in different areas:

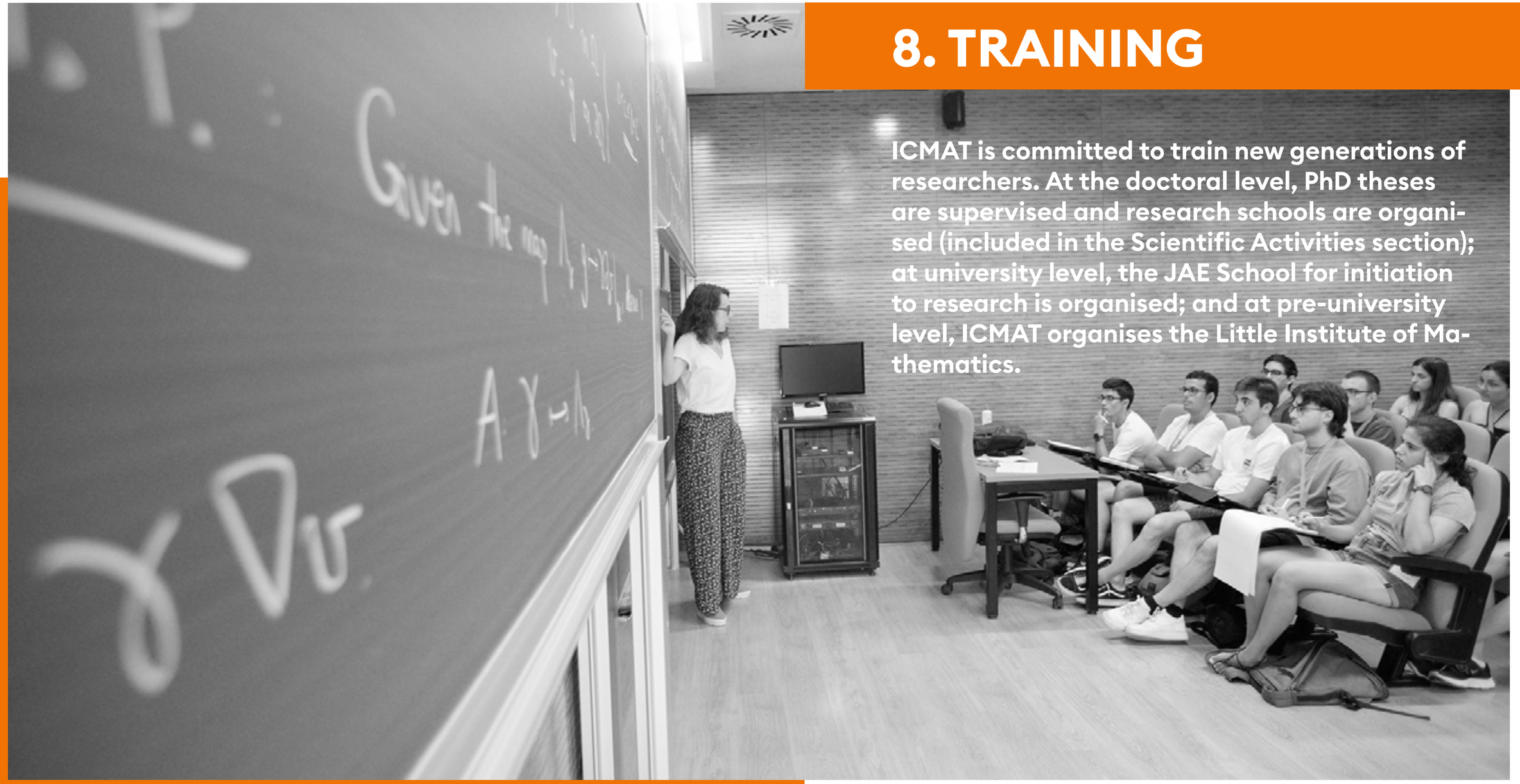
Analysis and Applications Seminar
Analysis and PDEs Seminar
Applied Mathematics Seminar
Algebraic Geometry, Arithmetic Geometry and Commutative Algebra
DataLab Seminar
Geometry Seminar
Geometry, Mechanics and Control Seminar
Group Theory Seminar
Machine Learning Seminar
Number Theory Seminar
PDEs and Fluid Mechanics Seminar
PDE UAM-ICMAT Seminar
Q-Math seminar
Other seminars

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

The Junior Colloquium is an activity organised by pre-doctoral researchers, which aims to establish links between young investigators in mathematics in the Community of Madrid, as well as to raise awareness of the various areas of research that they are developing. A meeting is held approximately every two weeks (usually on Wednesdays at at 17:00h), which takes place between ICMAT and UAM, where there is a presentation and an informal discussion.

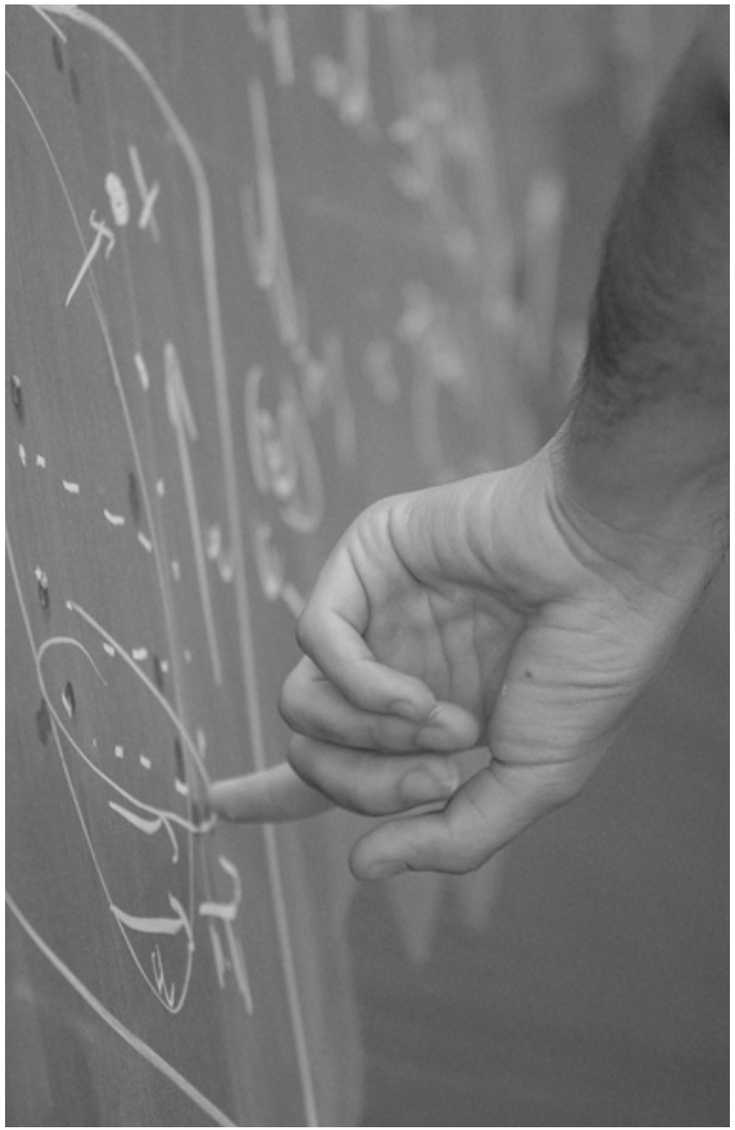
- "Homogeneización: cómo acabar con la complejidad de un sistema tomando perspectiva", Joaquín Domínguez de Tena (ICMAT-UCM) (17 January)
- "Matemáticas y democracia (I): Sistemas de votación ordinales y Teorema de Arrow", Andrés Laín Sanclemente (ICMAT-UAM) (31 January)
- "Mecánica de fluidos: origen, modelización y aplicaciones", José Antonio Lucas Manchón (ICMAT) (14 February)
- "Categorías monoidales y razonamiento diagramático", Arnau Mas Dorca (ICMAT-UC3M) (28 February)
- "Indecidibilidad del gap espectral", Laura Castilla Castellano (ICMAT-UCM) (13 March)
- "Multiplicadores de Schur y análisis armónico", Eduardo Tablate Vila (ICMAT) (3 April)
- "Existence of infinitely many normalized solutions for mass-supercritical nonlinear Schrödinger equations on noncompact metric graph with localized non-linearities", Pablo Carrillo Martínez (Université de Bourgogne Franche-Comté) (17 April)
- "Matemáticas y democracia (II): Manipulabilidad. Teorema de Gibbard-Satterthwaite", Andrés Laín Sanclemente (ICMAT-UAM) (8 May)
- "Foundations of support vector machines. The role of kernels", Diego Serrano Ortega (Universidad Autónoma de Madrid) (22 May)
- "Invertibilidad de funciones Sobolev: valores de frontera", David Mur Callizo (Universidad Autónoma de Madrid) (5 June)
- "Introducción al Mapping Class Group 1", Sergio Domingo Zubiaga (ICMAT) (19 June)
- "Formalismo matemático y control de redes neuronales para el aprendizaje supervisado", Antonio Álvarez López (UAM) (28 June)
- "De las ecuaciones de Maxwell a la geometría compleja: Una invitación a la Teoría Gauge", Diego Ruiz Cases, ICMAT-UCM (25 September)
- "A different angle on Fourier transform", Jorge Pérez García (ICMAT-UAM) (9 October)
- "Grafos de Cayley con un conjunto de geodésicas regular", Paloma López Larios (UCM) (23 October)
- "Variedades de Caracteres en Teoría de Nudos: de los invariantes de nudos a las TQFTs", Alejandro Calleja Arroyo (ICMAT-UCM) (6 November)
- "Moser vs De Giorgi", Marcos Llorca Climent (UAM) (20 November)
- "La geometría del ¿Por qué?", Carlos García Meixide (ICMAT-UAM) (4 December)
- "Anillos de división al servicio de la teoría de grupos", Pablo Sánchez Peralta (ICMAT-UAM) (18 December)
- "Complex geometry in dimension 8", Luis Pizarro Golvano (Universidad de Zaragoza)

8. TRAINING



ICMAT is committed to train new generations of researchers. At the doctoral level, PhD theses are supervised and research schools are organised (included in the Scientific Activities section); at university level, the JAE School for initiation to research is organised; and at pre-university level, ICMAT organises the Little Institute of Mathematics.

Theses



Seven researchers completed their PhD theses at ICMAT in 2024.

The Geometry of Dissipation, Asier López Gordón

Advisor: Manuel de León (ICMAT-CSIC)
Date: September 2024

Reduction by fiberwise actions and higher-order reduction in Field Theory, Álvaro Rodríguez Abella

Advisors: Marco Castrillón López (UCM)
Date: May 2024

H-Principles for Holomorphic Partial Differential Relations, Guillermo Sánchez Arellano

Advisors: Luis Giraldo Suárez (UCM) and Francisco Presas Mata (ICMAT-CSIC)
Date: April 2024

Multiplicadores de Schur suaves e idempotentes, Eduardo Tablate

Advisors: José Manuel Conde Alonso (ICMAT-UAM) and Javier Parcet Hernández (ICMAT-CSIC)
Date: March 2024

New approaches for the Hull-Strominger system: Futaki invariants and harmonic metrics, Raúl González Molina

Advisor: Mario García Fernández (ICMAT-CSIC)
Date: February 2024

Approximately holomorphic techniques in foliations, Samuel Ranz

University: Universidad Autónoma de Madrid
Advisors: Francisco Presas Mata (ICMAT-CSIC) and Luis Guijarro (ICMAT-UAM)
Date: January 2024

A Mathematical and Computational Approach to the Study of Transport in Ocean Flows, Guillermo García Sánchez

Advisor: Ana María Mancho (ICMAT-CSIC)

JAE School

The JAE School of Mathematics 2024 took place from 24 June to 5 July. Organized by ICMAT every summer, it is aimed at bachelor and master's students who are interested in learning about research in mathematics and its applications. Over two weeks, students are introduced to areas of mathematics outside the undergraduate curriculum. The goal of the School is to encourage students to pursue a career in research and to interact with the high-level mathematicians who give the courses.

In 2024, the programme included six mini-courses and five introductory talks on current research issues in a wide range of fields, from number theory to geometry, differential equations or algebra. The lectures were given by expert researchers in these fields, not only from ICMAT but also from other prestigious institutions such as the Massachusetts Institute of Technology (MIT, USA) or the Swiss Federal Institute of Technology in Zurich (ETH, Switzerland). Some of them, such as María Ángeles García-Ferrero (ICMAT-CSIC), Javier Fresán (Sorbonne University, France) or Daniel Álvarez-Gavela (MIT), were once students at the JAE School.

This year 104 participants registered: 90 of them attended the full programme, the rest only attended one of the two weeks. All students who applied were admitted and attendance was free for all of them. Although 60% of the students came from Madrid, 32% of the students in 2024 were from other parts of Spain and 7% from universities in Mexico, Peru, Ecuador and the USA. Most of the students were studying for a degree in mathematics (70% of the total), 11.5% for a double degree with mathematics and 15.4% for a master's or doctoral degree. In addition, four high school students, winners of Mathematics Olympiads, participated.

In 2024, the School was organized by Daniel Peralta-Salas (ICMAT-CSIC) and Diego Córdoba (ICMAT-CSIC), director of the centre's Severo Ochoa programme.

Among those attending the school, 25 of them were beneficiaries of the Severo Ochoa 2024 (INTRO-SO) grant programme for introduction to research. In addition to participating in the courses and lectures, over the course of a month they had the opportunity to carry out a scientific project with an ICMAT researcher as a tutor.

PIM


Image: ICMAT

The Little Institute of Mathematics (Pequeño Instituto de Matemáticas, PIM) is a project of ICMAT in collaboration with the Department of Mathematics of UAM and RSME (Real Sociedad Matemática Española), aimed at people between 12 and 18 years of age. It consists of weekly problem-solving sessions, which are held on Fridays from 17:30 to 20:00 at ICMAT.

Its main objective is to foster interest in mathematics and to encourage students to enter this fascinating world. The teaching philosophy behind the project can be summed up in one simple sentence: 'Mathematics is not learned by seeing, but by doing'. And this means solving difficult problems, looking for different approaches, trying multiple paths, talking to other people, contrasting ideas. Following the methodology of mathematical circles, students do not learn new concepts in theoretical sessions, but work in groups on problem sheets, and are supported by the teaching staff, mainly pre-doctoral research staff.

The second edition concluded on 31 May 2024, with the participation of some 140 students from 1st ESO to 2nd Baccalaureate, 35% of them women. The third edition of the programme began in September 2024, with a record number of 150 participants

9. AWARDS AND DISTINCTIONS

In 2024 the excellence of the ICMAT's scientific staff has been recognised with various national and international awards and mentions.

ICMAT receives accreditation as a Severo Ochoa Centre of Excellence for the fourth consecutive time

Image: Ministerio de Ciencia, Innovación y Universidades

ICMAT has been accredited, for the fourth consecutive time, as a 'Severo Ochoa' Centre of Excellence by the Ministry of Science, Innovation and Universities, through the State Research Agency (AEI). Since its foundation in 2007, the Institute has maintained a firm commitment to excellence in mathematical research, with outstanding research staff in their respective fields.

Thanks to this new accreditation, ICMAT will receive funding of 4.5 million euros until 2028 for its institutional strengthening.

More info

Claire Voisin, member of ICMAT's External Scientific Advisory Committee, receives the BBVA Foundation Frontiers of Knowledge Award

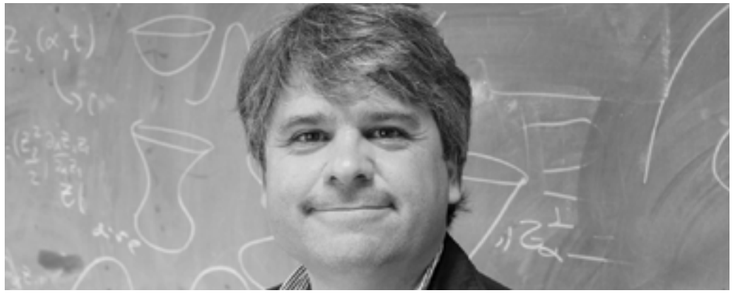
Image: Fundación BBVA

On February 2024, the BBVA Foundation announced the names of the winners of its 16th Frontiers of Knowledge Award in Basic Sciences. This year's winners were Claire Voisin of the French National Centre for Scientific Research (CNRS) and Yakov Eliashberg of Stanford University (USA). The jury singled out both researchers for their outstanding contributions in the areas of algebraic and symplectic geometry and the links between the two.

Both Voisin and Eliashberg have a close relationship with ICMAT. Since 2020, Voisin has been a member of its External Scientific Advisory Committee and is very close to the group of Oscar García-Prada, CSIC research professor at ICMAT. Eliashberg is in contact with the group of Francisco Presas, CSIC research scientist at ICMAT.

More info

Diego Córdoba becomes corresponding member of the Royal Academy of Sciences



Diego Córdoba, scientific director of the Severo Ochoa Programme of Excellence at ICMAT, research professor of CSIC at ICMAT and winner of the 2023 National Research Award, is one of the six academicians who joined the Royal Academy of Exact, Physical and Natural Sciences (RAC) in December 2024.

Córdoba entered as a corresponding academician in the section of Mathematical Sciences, in the scientific area of equations in partial derivatives.

More info

Antonio Córdoba receives the Ferran Sunyer i Balaguer 2024 Award

Image: Institut d'Estudis Catalans

Antonio Córdoba, professor emeritus at Universidad Autónoma de Madrid and member of ICMAT, won the Ferran Sunyer i Balaguer 2024 International Mathematical Research Prize, awarded by the foundation of the same name. The Scientific Committee of the award recognised his monograph Suprematism in Harmonic Analysis, which presents recent advances in the area of harmonic analysis. The announcement was made on 23 April 2024 at a ceremony held at the headquarters of the Institut d'Estudis Catalans, in Barcelona, as part of the Institut's Sant Jordi Awards.

The prize is worth €15,000 and includes the publication of the monograph in the 'Progress in Mathematics' collection, published by Birkhäuser.

More info

José Manuel Conde Alonso is awarded with the Universidad Autónoma de Madrid prize for young researchers

The Universidad Autónoma de Madrid (UAM) recognises, on an annual basis, young researchers under the age of 40 who have made a significant contribution to the development of research activity at the University. The main objective of these awards is to recognise and make visible the work of these researchers for their contribution to scientific development, as well as their national and international visibility as a benchmark research centre.

In the 2024 call, José Manuel Conde Alonso, researcher at ICMAT and UAM, was recognised with this award in the area of Mathematical Sciences and Theoretical Physics.

Álvaro Romaniega's thesis, among those awarded as Relevant Doctoral Thesis of the CSIC

Image courtesy of Romaniega

Álvaro Romaniega's thesis, under the direction of Daniel Peralta-Salas (ICMAT-CSIC) and Alberto Enciso (ICMAT-CSIC), was one of those selected for the 2nd CSIC Relevant Doctoral Thesis Award. It is one of the four awarded in the global area Society, among the 20 in total. In this edition, 190 proposals were received.

Romaniega presented his thesis, "Asymptotic probability techniques in monochromatic waves and fluid mechanics", in September 2022 at ICMAT.

More info

Javier Peñafiel, winner of the 'Yo investigo. Yo soy CSIC' contest for popular science videos

Javier Peñafiel Tomás, pre-doctoral researcher at ICMAT and CSIC, was one of the winners of the 5th edition of the competition Yo investigo. Yo soy CSIC, organised by the CSIC Postgraduate Department, in which pre-doctoral researchers tell the story of their thesis in an informative way in audiovisual format and in less than three minutes. Peñafiel explained in his video how mathematics can help to understand the movement of fluids, one of the great challenges in current research.

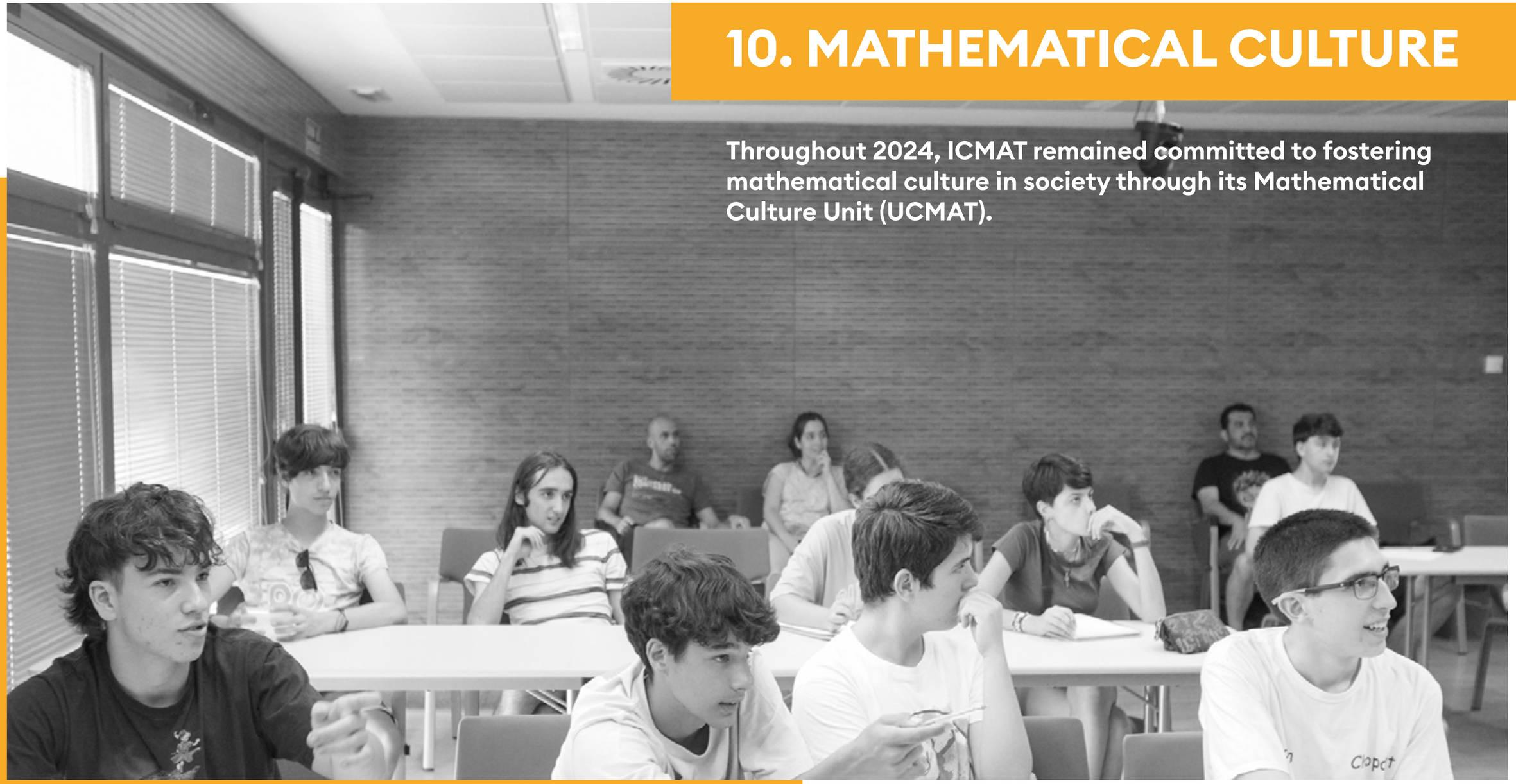
More info

Carlos García Meixide wins a Student Travel Award of the Institute of Mathematical Statistics (IMS)

Carlos García Meixide was awarded a Student Travel Award of the Institute of Mathematical Statistics (IMS) for his paper "Uncertainty Quantification for Intervals", co-authored with Michael Kosorok (UNC Chapel Hill), Marcos Matabuena (Harvard) and Michael Kosorok (UNC Chapel Hill).

García Meixide presented his paper in the 2024 IMS International Conference on Statistics and Data Science (ICSDS) special Student Travel Award sessions and received award certificate with US$800 during the award ceremony on 19 December 2024.

10. MATHEMATICAL CULTURE



Throughout 2024, ICMAT remained committed to fostering mathematical culture in society through its Mathematical Culture Unit (UCMAT).

This unit, in collaboration with the Institute's scientific staff, develops a wide range of dissemination resources aimed at communicating both ICMAT's mathematical activities - new scientific results, events, visits by outstanding mathematicians or the awarding of grants and prizes - and mathematics in general to a wider audience. These materials, delivered in 2024 through various formats and platforms, include 70 pieces - news articles, interviews and reports - published on the ICMAT website, some of which are also distributed to the media as press releases, as well as videos.

Another communication channel of ICMAT is the ICMAT Newsletter: a monthly bulletin that provides updates on the centre's latest developments, including news, activities, projects, visitors, and more. Anyone interested can subscribe to the newsletter through this link.

The unit further extends its reach through active engagement on social media. ICMAT maintains a strong presence on major platforms, including: Facebook (33 000 followers as of January 2025), X (30 300 followers), Instagram (1644 followers), YouTube (4040 subscribers; 300 114 views), Linkedin (1214 followers). To the activity on these networks, ICMAT has now added a profile on the BlueSky social network (with 529 subscribers).

ICMAT staff regularly **collaborate with media outlets,** either in response to specific requests from journalists or through initiatives developed by the Mathematical Culture Unit. In 2024, over 50 pieces mentioning ICMAT or its staff members have been published.

Among these collaborations, 'Café y Teoremas' stands out as a notable example. 'Café y Teoremas' is a monthly feature curated by ICMAT and published in El País. This column focuses on mathematics, offering a platform where members, and collaborators of the centre highlight recent advancements in the field and explore the intersections of mathematics with various social and cultural domains. 14 articles appeared in 2024.

OUTREACH ACTIVITIES

4º ESO+Empresa

ICMAT is participating in the Community of Madrid programme 4ºESO+Empresa (4th Grade Secondary Education + Company), which provides young students with the chance to carry out educational visits to companies and research centres. In 2024, 30 students were able to spend three days getting to know the daily activity of ICMAT, with the purpose of showing these students the type of work is done at the Institute and to stimulate scientific vocations. These students attended talks and wokshops given by ICMAT personnel, such as Javier Aramayona (ICMAT-CSIC), Piergiulio Tempesta (ICMAT-UCM), Enrique García-Sánchez (ICMAT-CSIC), Henrique Souza (ICMAT), Asociación QED UAM, María Ángeles García-Ferrero (ICMAT-CSIC), Ricardo Martínez de Madariaga (CFTMAT-CSIC) and Laura Castilla Castellano (ICMAT-UCM).

Mathematics at the Residencia

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

In 2024, the following talks were celebrated:

"Cuando el arte contemporáneo mira a las matemáticas"

Speaker: Raúl Ibáñez Torres

Date: 7 March 2024

Image: Residencia de Estudiantes

"Caos: de la teoría a la música"

Speaker: Laura Farré Rozada

Date: 2 December 2024

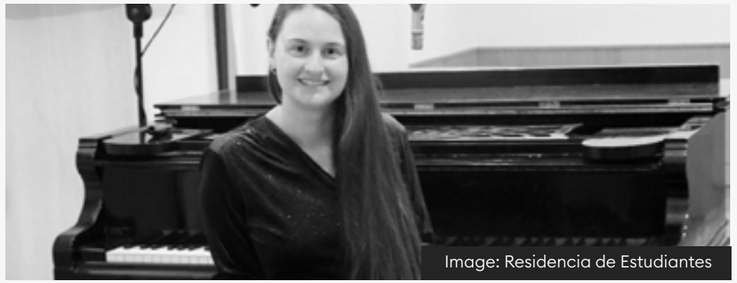


Image: Residencia de Estudiantes

European Researchers' Night

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

In 2024, the European Researchers' Night was celebrated on 27 September. ICMAT participated in the joint activity organized by the CSIC centres at Campus de Cantoblanco, entitled "El CSIC te llama esta noche". A large open fair has been organised in Fundación Espacio Telefónica to welcome people interested in learning about the science being done in these centres. There were workshops, scientific demonstrations, monologues and an exhibition (Escape-road: "A la búsqueda de las científicas Nobel y no Nobel"), on a wide range of research topics. The activity, as part of NIGHTMADRID, a science outreach project, coordinated by Fundación madri+d and funded by the European Union within the Horizon Europe Programme, under the Marie Skłodowska-Curie actions.

ICMAT organised the workshop "Una mirada matemática a los superhéroes", given by María Ángeles García-Ferrero and Alba García, ICMAT researchers.

Science Week

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

On 5 and 6 November 2024, the Institute organised the following activities:

5 november. Conference: **“Números que brillan: matemáticas en imágenes cotidianas”,** given by Fernando Chamizo (ICMAT-UAM)

6 November. Workshop: **“Los límites de la computación”,** led by Laura Castilla Castellano (ICMAT-UCM)

Initiative for Mathematics and the Arts

Iniciativa por las Matemáticas y las Artes (IMA – Initiative for Mathematics and the Arts) is a platform created with the aim of promoting joint activities between mathematics and the Within the framework of this initiative, ICMAT organised the following activities in 2024:

“Quipus: matemáticas y relatos incas”

Scientific literary round table with the author of El Espía del Inca, Rafael Dumett; Manuel de León, CSIC researcher at ICMAT; and the philologist Concepción Reverte Bernal (Universidad de Cádiz). They discussed, in Librería Cervantes y Compañía (Madrid), about this novel and the quipus, knotted strings that were used in the Inca empire to represent numbers and other concepts, protagonists of the story. In addition, ICMAT organised a contest on social networks with the aim of disseminating this activity and raising awareness of Inca mathematics. The three winners received a set of Dumett books.

Contest of the film Marguerite’s Theorem

This French film stars a PhD student in mathematics at the prestigious Ecole Supérieure de Paris. ICMAT organised a competition on its social networks to attend the preview of the film in Madrid and Barcelona.

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

ICMAT has joined in celebrating 11 February, International Day of Women and Girls in Science since 2018. Yamilet Quintana, postdoctoral researcher at ICMAT and assistant professor at the Universidad Carlos III de Madrid, gave a workshop “Calculating the area and perimeter of plane figures with homogeneous intelligent groups” for high school students in 2024.

More information in page 58 of this annual report.

Europe Day

ICMAT took part for the first time in 2024 in the activities coordinated by the CSIC institutes of the Cantoblanco Campus on the occasion of Europe Day, commemorated on 9 May. These activities were organised for secondary school students.

Andrés Laín, pre-doctoral researcher at ICMAT, presented the project funded by the European Research Council (ERC) on which he is working: 'Non-local dynamics in incompressible fluids', on 8 May. For her part, María Ángeles García Ferrero, CSIC senior scientist at ICMAT, participated as a guide in the Escape Road: In search of Nobel and non-Nobel women scientists, on 9 May.

School visits

Every year, ICMAT receives visits from students from different educational levels, with the aim of showing them the centre's activities, the mathematics research career, the people who develop it, etc. In 2024, 25 students of the Colegio Sagrado Corazón Fuencarral (Madrid) visited ICMAT.

Audiovisual Communication

UCMAT produces and uploads videos (public lectures, interviews, outreach videos, institutional reports, dissemination of calls for proposals), on the ICMAT YouTube channel and on social media.

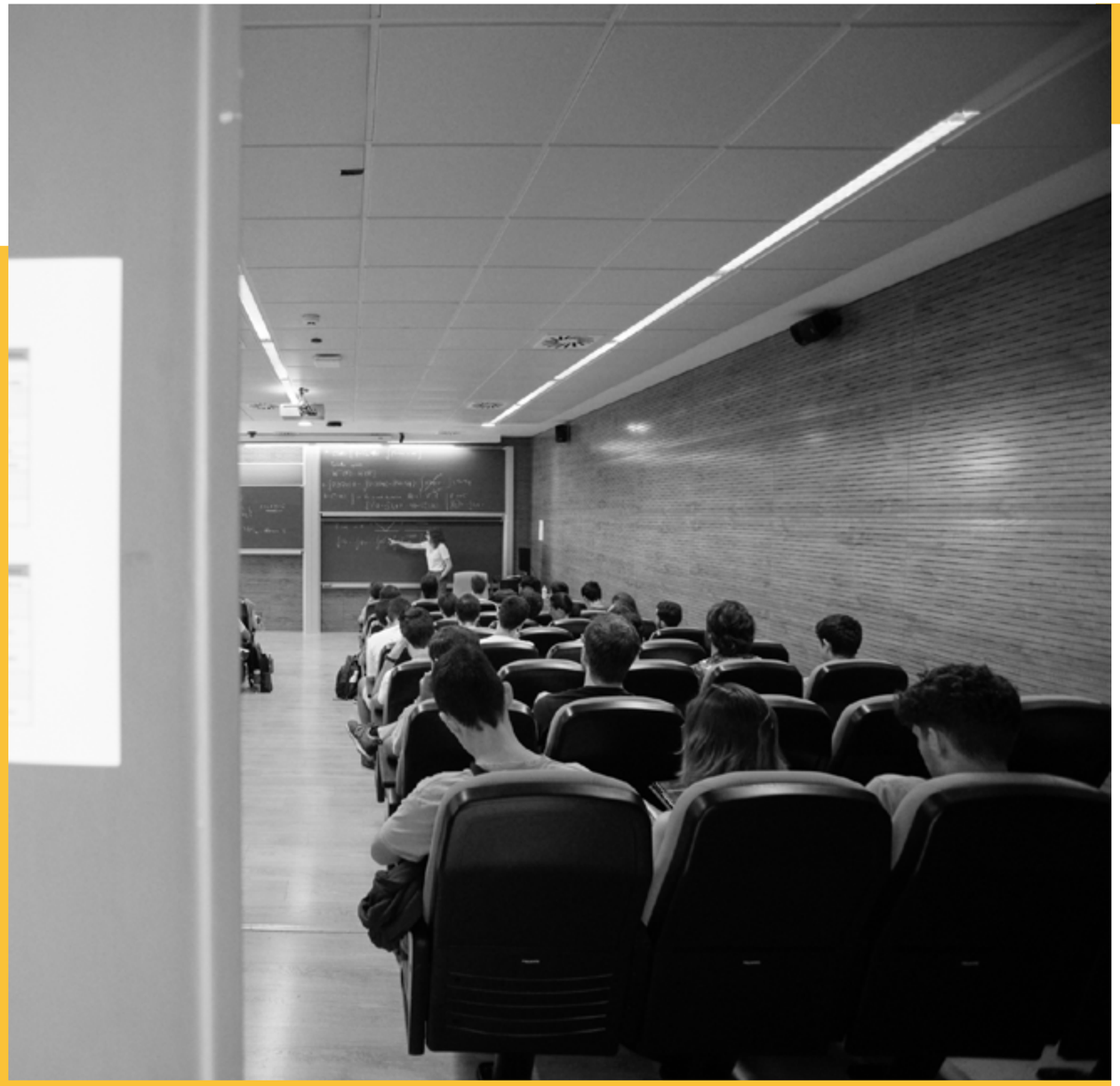
May 12, Celebrating Women in Mathematics

On 13 May, ICMAT celebrated the international women in mathematics day with a live conversation on Instagram with one of its researchers: María Inés de Frutos Fernández. It was an opportunity to learn about the work and career of a young researcher in mathematics.

More information in page 58 of this annual report.

Science in Action

Science in Action is a competition based on innovative ideas to bring science closer to the general public. Those selected in the first phase present their proposals live in a grand finale that become a great celebration of science. Together with other scientific institutions, ICMAT supports this initiative financially and is part of the scientific jury that selects the finalists.



11. EQUALITY ACTIONS

Since 2016 ICMAT has had an **ICMAT Equality Committee**, which demonstrates its commitment to promoting inclusivity and diversity through its programmes and collaborations. These initiatives not only celebrate the achievements of underrepresented groups in STEM, but also inspire future generations to pursue careers in science and mathematics.

During 2024, the Equality Committee of ICMAT was composed of Ana Bravo (ICMAT-UAM), José M. Conde (UAM-ICMAT), Edmundo J. Huertas (UAH), Marta Macho-Stadler (Universidad del País Vasco), David Martín de Diego (ICMAT-CSIC), Yamilet Quintana (UC3M-ICMAT), and Nuria Torrado (ICMAT-UAM), who served as the chairperson.

Throughout the year, the Equality Committee organized and participated in a variety of initiatives aimed at promoting equality and diversity within the scientific community.

11 February, International Day of Women and Girls in Science

One of the highlights of the year was the celebration of the International Day of Women and Girls in Science on 11 February. As part of this celebration, Yamilet Quintana, a member of the committee and Assistant Professor at Universidad Carlos III de Madrid, conducted a workshop titled "Calculating the Area and Perimeter of Planar Figures with Homogeneous Intelligent Groups." Thirty first-year high school students participated in this activity, enhancing their understanding of mathematical concepts through the construction of mosaics with tangram puzzle pieces. Additionally, the Intercenter Equality Network UAM+CSIC, to which ICMAT belongs, organized an exhibition called "Escape Road: In Search of Nobel and Non-Nobel Women Scientists." This event took place at the Marcos Ana Library in San Sebastián de los Reyes (Madrid) throughout February and featured interactive escape sessions and lectures by female researchers for educational institutions.

12 May, Celebrating Women in Mathematics

On 13 May, to commemorate International Women in Mathematics Day, María Inés c de Frutos-Fernández, a Margarita Salas Postdoctoral Researcher at ICMAT and Universidad Autónoma de Madrid, participated in a live interview. This event provided an opportunity to learn about her work in mathematical formalization and number theory. She shared insights into her research career, the motivations behind her decision to study mathematics, and her experiences as a researcher abroad.

STEMatEsElla Programme

Image: Ana Bravo

Another major initiative supported by the committee was the fifth edition of the STEMatesElla mentoring programme, which took place during the first half of the year. This programme, organized by the Spanish Association of Executives and Counselors (EJE&CON) and the Royal Spanish Mathematical Society (RSME), in collaboration with ICMAT, Akermann International, and the Basque Center for Applied Mathematics (BCAM), connected female students in the final stages of their undergraduate or master's studies in STEM fields with professional women in science and business. The closing ceremony for this edition, along with the launch of the sixth edition, was held on 11 October at ICMAT. Registration for the new edition closed on 20 December..

Science by Women programme, Women for Africa Foundation

Through the Science by Women programme, of Women for Africa Foundation, ICMAT is set to host Babel Raïssa Guemdjo Kamdem, a researcher from an African country selected as part of the tenth edition of the Science by Women programme launched in September 2024. During her six-month stay at ICMAT in 2025, she will collaborate with the research group led by David Ríos on a project titled “Novelty Detection Using Kernel Null Foley-Sammon Transform.”

Equality Intercenter Network CSIC

In July, the committee contributed to the Equality Cycle organized by CBM and the Intercenter Network CSIC-UAM. As part of this initiative, Aitor Villafranca, Director of Education at PRISMA, delivered a seminar on 10 July titled “LGTBIQIA+ Diversity in Science: Current Situation and Actions for Equality.” This seminar addressed the importance of fostering inclusion and diversity in scientific disciplines.

12. CREDITS

Instituto de Ciencias Matemáticas (ICMAT)
C/ Nicolás Cabrera, 13-15
28049 Madrid, Spain
www.icmat.es

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