

2023



Activity Report

Activity Report

2023

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01. Introduction



Scientific Director

José A. Lozano

In the realm of mathematical inquiry, the late Fields Medalist Maryam Mirzakhani once remarked: “[The beauty of mathematics only shows itself to more patient followers](#)”. These words encapsulate not only the ethos but also the journey of the Basque Center for Applied Mathematics (BCAM) as it continues to push the boundaries of mathematical research and its applications.

As we embark on this journey of reflection and progress, we are proud to present the annual activity report of BCAM, [a reflection to our unwavering commitment to excellence and innovation](#). In the past year, BCAM has achieved significant milestones, underscoring our position as a premier hub for mathematical research and collaboration.

One of the hallmarks of our success lies in the [quality of our research indicators](#). With a total of 175 publications, BCAM continues to contribute groundbreaking insights to the mathematical community and beyond. This prolific output is a testament to the dedication and expertise of our researchers, whose tireless pursuit of knowledge drives our collective mission forward.

Moreover, [BCAM has experienced remarkable growth](#), with our ranks swelling to over 200 researchers by December 2023. This expansion speaks volumes about the vitality of our institution and underscores our commitment to fostering a vibrant intellectual environment where ideas flourish and collaborations thrive.

A highlight of the past year has been the establishment of the [new international strategic lab on Singularity Theory](#) in partnership with the Renyi Institute, Mainz University, and KU Leuven. This groundbreaking initiative promises to unlock new frontiers in mathematical research and forge lasting connections across borders.

In addition to our academic achievements, BCAM has also secured two prestigious European projects, namely “TANGO – It takes two to tango: a synergistic approach to human-machine decision making”; and Project OpenSuperQPlus of the European Flagship for Quantum Technologies. These projects underscore our leadership in pioneering interdisciplinary research at the intersection of mathematics and technology.

Furthermore, [BCAM has redoubled its efforts in knowledge transfer and utilization \(KTU\)](#), leveraging our research insights to address real-world challenges and drive societal impact. Through strategic partnerships and innovative initiatives, we are harnessing the power of mathematics to shape a better future for all.

As we reflect on these achievements, we are reminded of Maryam Mirzakhani’s words and the enduring truth they hold. The beauty of mathematics indeed reveals itself to those who persevere, who remain steadfast in their pursuit of knowledge and discovery. At BCAM, we are honored to be counted among these patient followers, and we remain steadfast in our commitment to unraveling the mysteries of the mathematical universe.

In the pages that follow, we invite you to explore the myriad facets of BCAM’s journey – from our groundbreaking research to our collaborative endeavors and everything in between. [Together, let us continue to push the boundaries of mathematical inquiry and unlock new realms of possibility](#). For in the words of Mirzakhani, the beauty of mathematics awaits those with the patience to seek it.

Finally, I would like to spend a few words of gratitude. [I would like to thank all the people of BCAM who feel the centre as a part of them](#). Thank you very much to those that organise activities: conferences, talks, courses, Light PhD seminars, and even chess contests. Those that contribute to communication and dissemination activities, knowledge transfer activities, and those that make this space strongly alive. I would like to add a special message of gratitude to our administrative staff, who carefully and patiently support our research activities and promote the centre.

[Let’s keep writing together the mathematics for the future.](#)

02. BCAM in numbers

2.1. Scientific Outputs¹

172

Indexed articles

81,9%

Q1

41,97%

D1

62

H Index

1899

BCAM publications are cited 6060 times in 2023 by 5139 documents

2.2. Grants in Place

International public projects

2

ERC

1

FET

6

Marie Skłodowska-Curie

2

HE Cluster 4 (Digital, Industry & Space)

24

Regional public projects

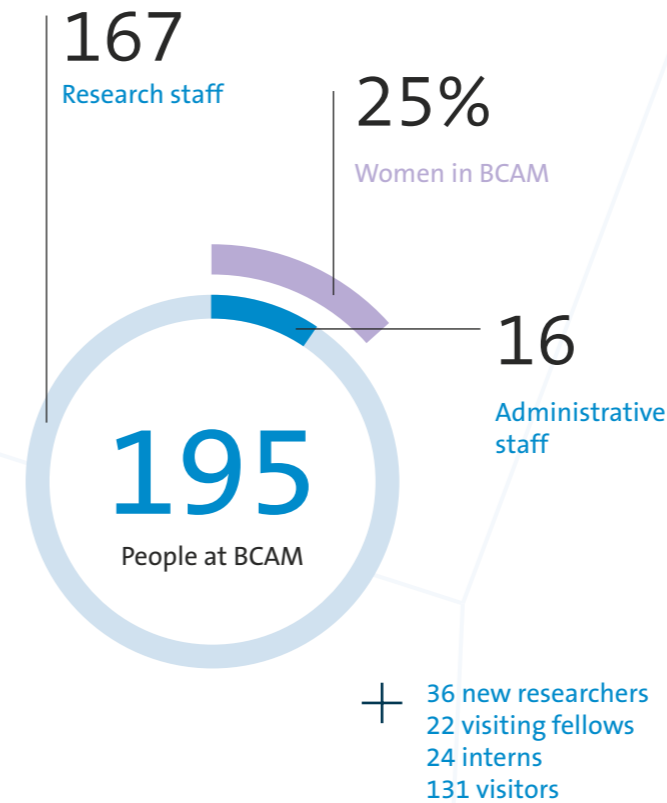
11

National public projects

11

Private projects

2.3. Personnel



2.5. Training and Knowledge Transfer

7 Defended Doctoral theses

45 Ongoing Doctoral theses

61 Ongoing Postdoctoral Trainees

6 Ongoing Joint Positions

2.4. Funding

7.67 M€

3.96 M€

Basque Country

2.67 M€

Spain

0.56 M€

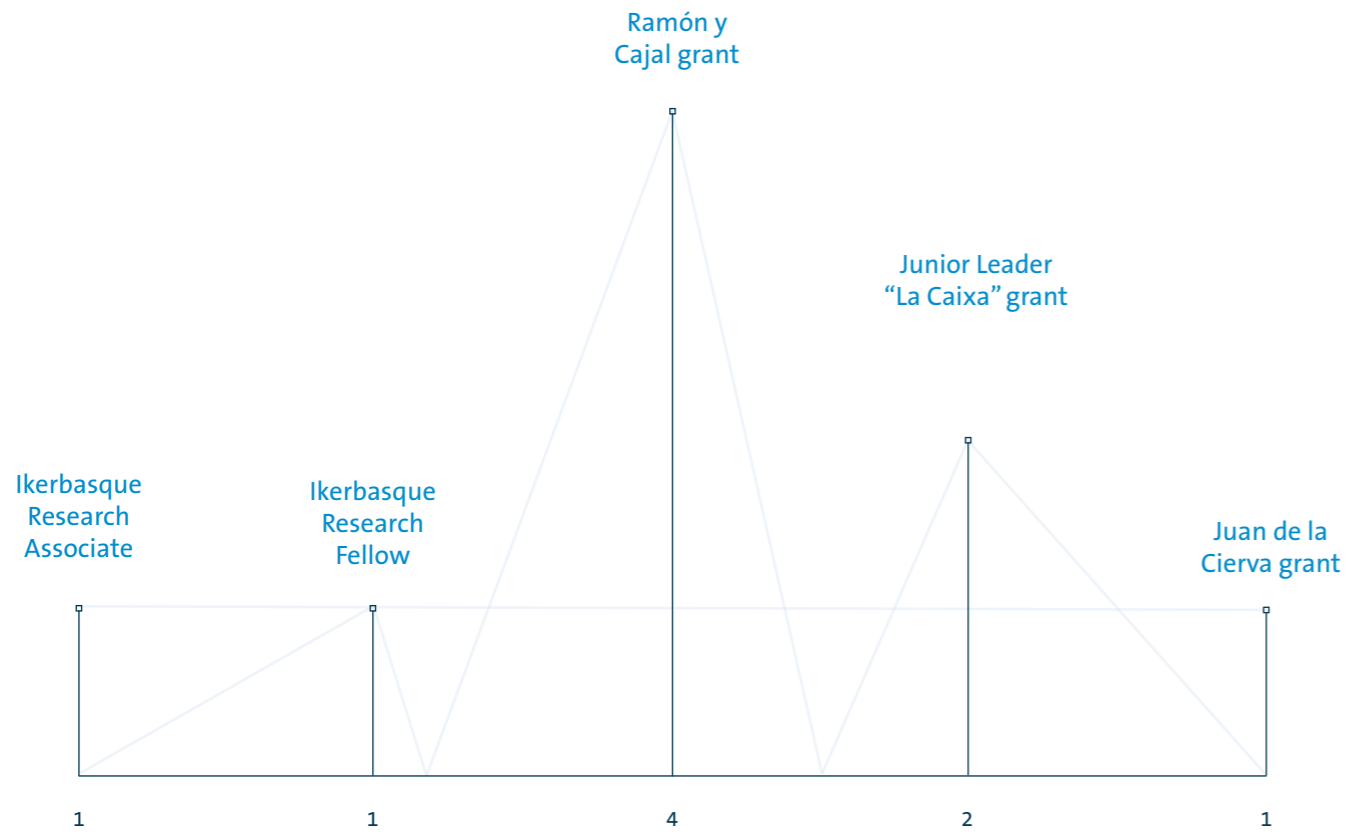
Europe

0.48 M€

Private & other

¹Year range: 2023. Data source: Scopus. Date exported: 27/02/2024.

2.6. Competitive individual grants



2.8. Social Media

Youtube

278	4.407	54.400
Subscribers	Views	Impressions

LinkedIn

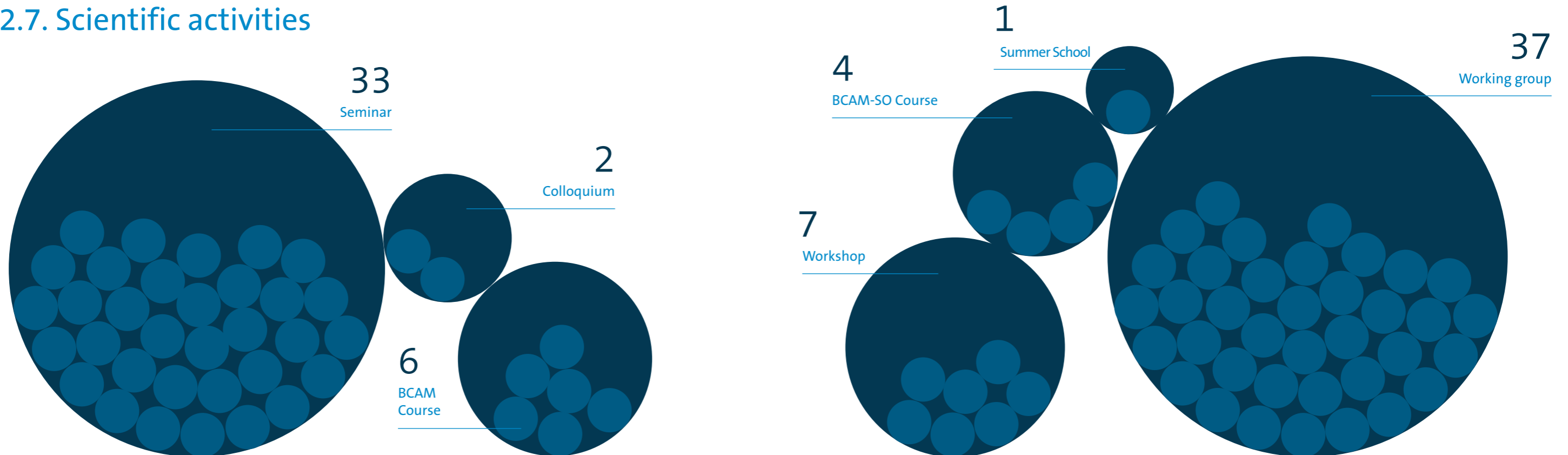
2.600	135	1.700	114.000
Followers	Posts	Reactions	Impressions

Twitter

2.300	278	151.100	292	1.100	643
Followers	Tweets	Impressions	Retweets	Likes	Replies

Data source: Hootsuite, Twitter, LinkedIn and Youtube. Data exported: 31/12/2023.

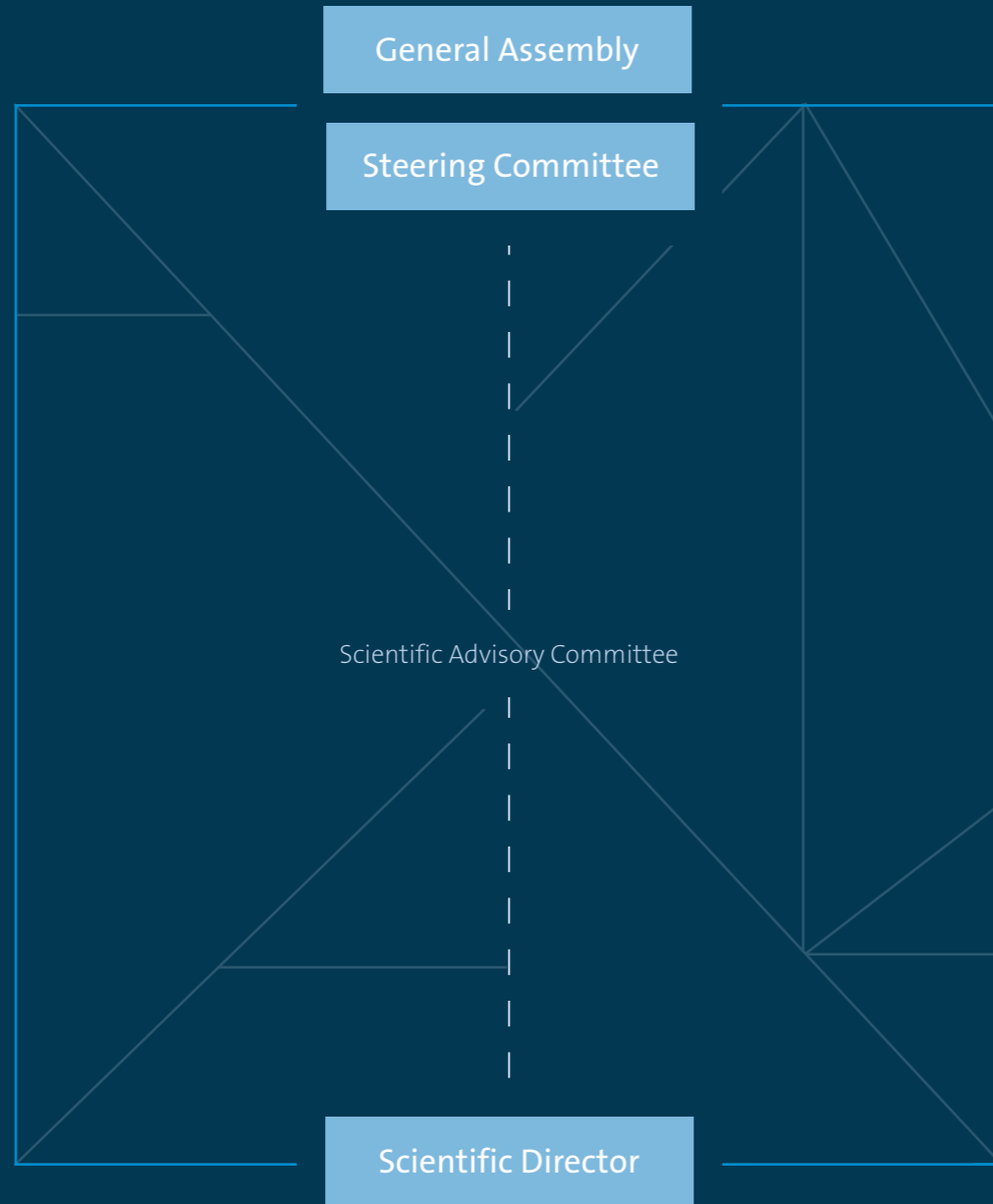
2.7. Scientific activities



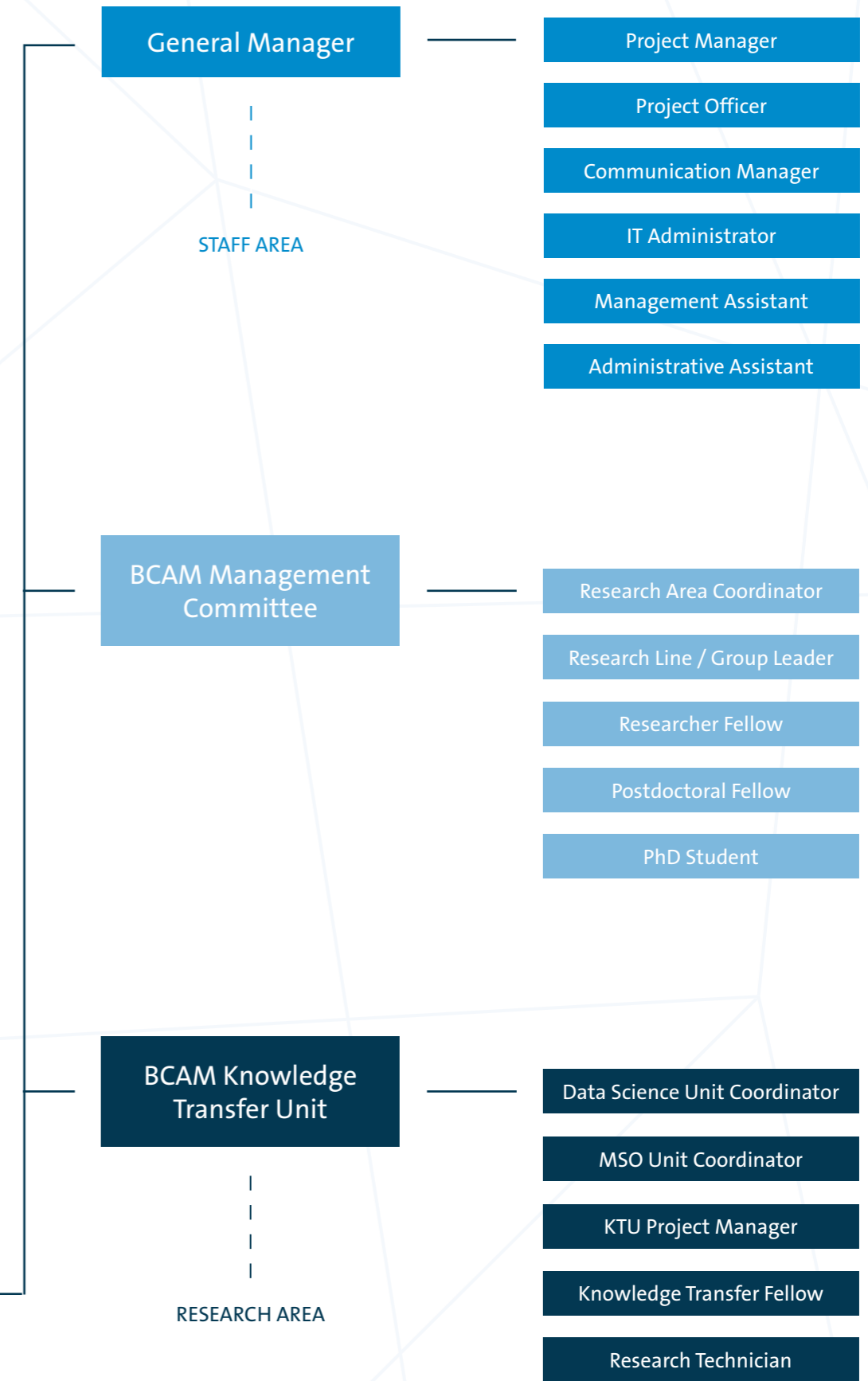
03. People

BCAM's organization chart

GOVERNANCE

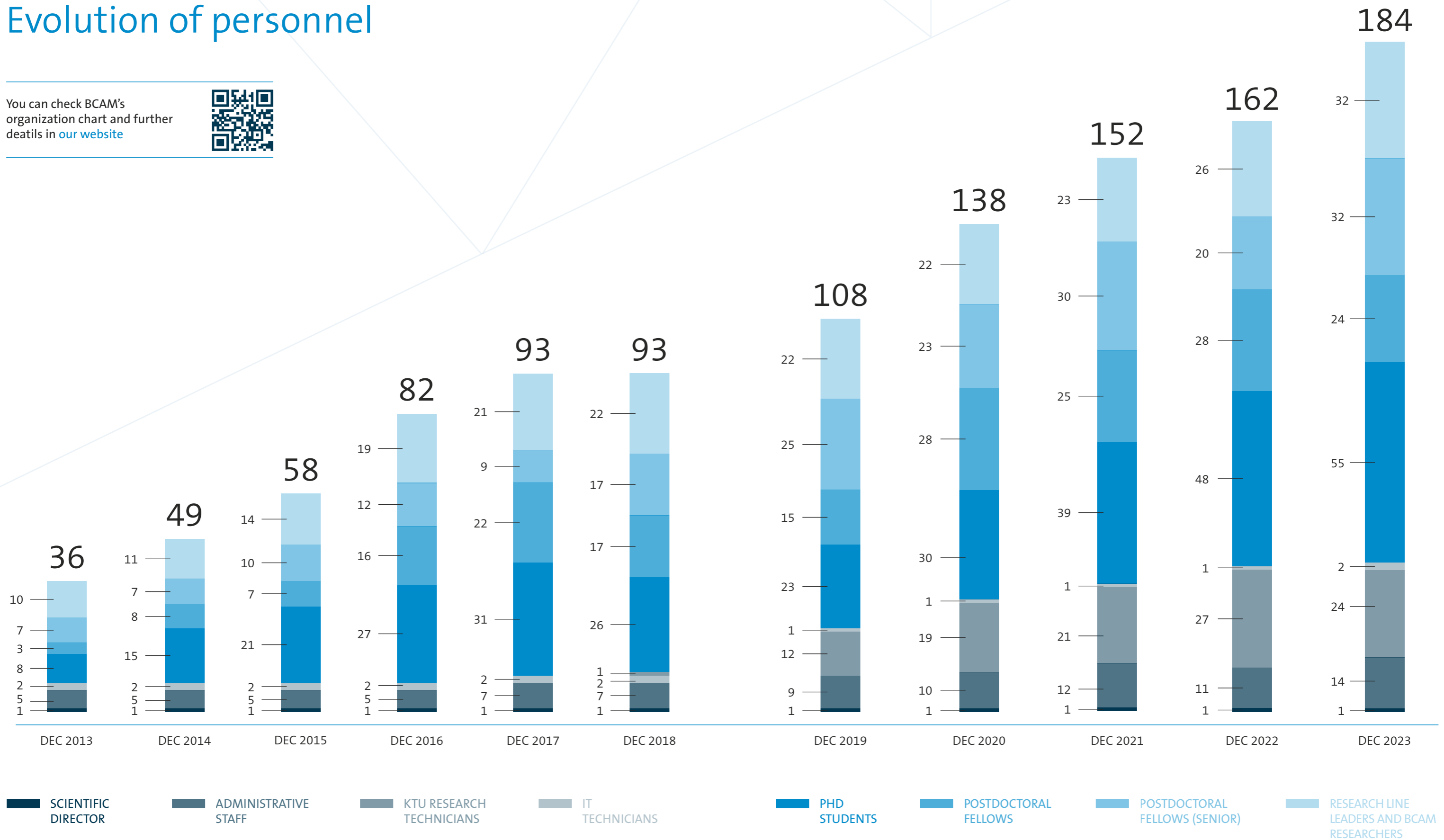


OPERATIONS



Evolution of personnel

You can check BCAM's organization chart and further details in [our website](#)



Research areas and lines

In 2023, BCAM remained dedicated to advancing its research agenda by fostering its established research groups and thematic research lines, organized into 5 distinct areas corresponding to its scientific focus.

Mathematical Physics

- | Quantum Mechanics - [QM](#)
- | Statistical Physics - [SP](#)
- | Singularity Theory and Algebraic Geometry - [STAG](#)

MP

Data Science and Artificial Intelligence

- | Combinatorial Optimization - [CO](#)
- | Applied Statistics - [AS](#)
- | Machine Learning - [ML](#)

DS

CM

Computational Mathematics

- | Mathematical Design, Modelling and Simulations - [MATHDES](#)
- | CFD Modelling and Simulation - [CFDMS](#)

01

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04

05

M3A

Mathematical Modelling with Multidisciplinary Applications

- | Modelling and Simulation in Life and Material Sciences - [MSLMS](#)
- | Mathematical and Theoretical Biology - [MTB](#)
- | Mathematical, Computational and Experimental Neuroscience - [MCEN](#)

APDE

Analysis of Partial Differential Equations

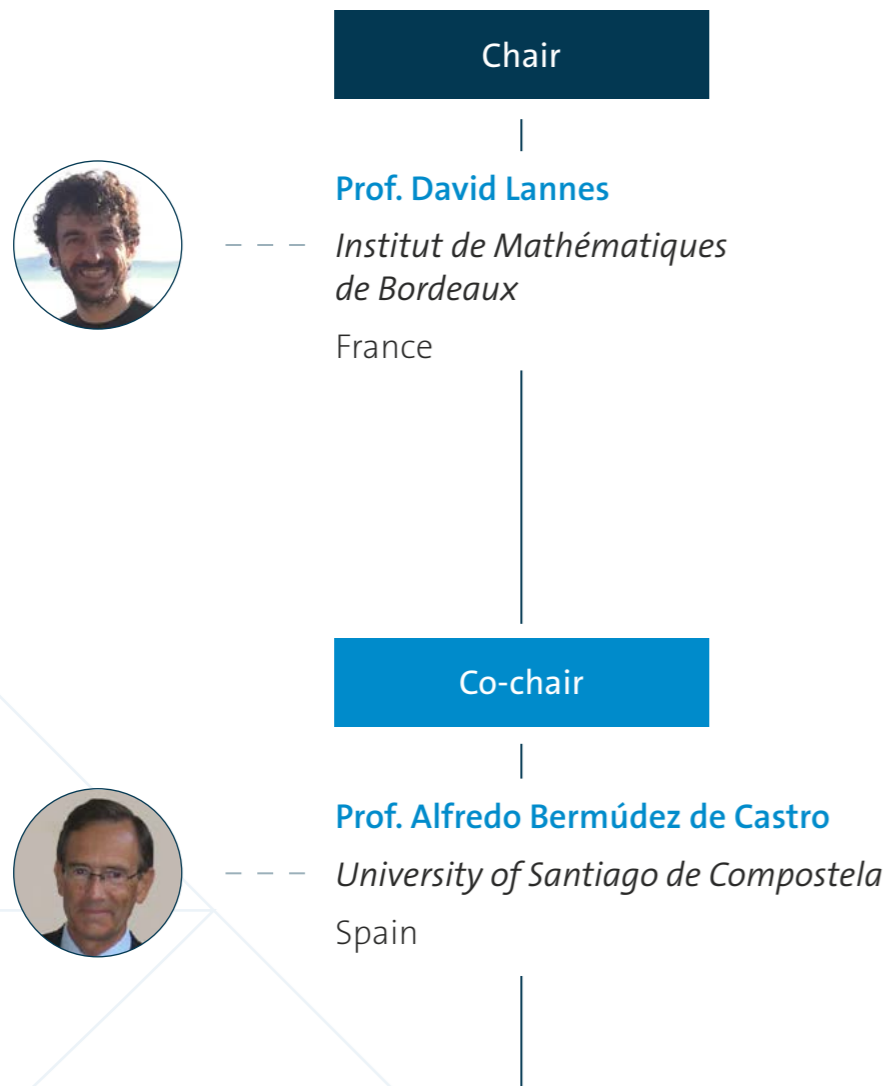
- | Linear and Non-Linear Waves - [WAVE](#)
- | Harmonic Analysis and Inverse Problems - [HA](#)
- | Applied Analysis - [AA](#)

BCAM Scientific Advisory Committee

The Scientific Committee is an external and strategic advisory council of BCAM made up of internationally recognised researchers in mathematics.

They provide an independent view of BCAM's researchers and activities.

This committee meets once a year to monitor the development of the centre's strategic plan, provide advice on different topics and validate the results obtained.



Prof. Annalissa Buffa

Institute de Mathématiques - École polytechnique Fédérale de Lausanne
Switzerland



Dr. Montserrat Fuentes

St-Edwards University
USA



Prof. Michael Ortiz

California Institute of Technology
USA



Prof. Laure Saint-Raymond

École Normale Supérieure de Lyon
France

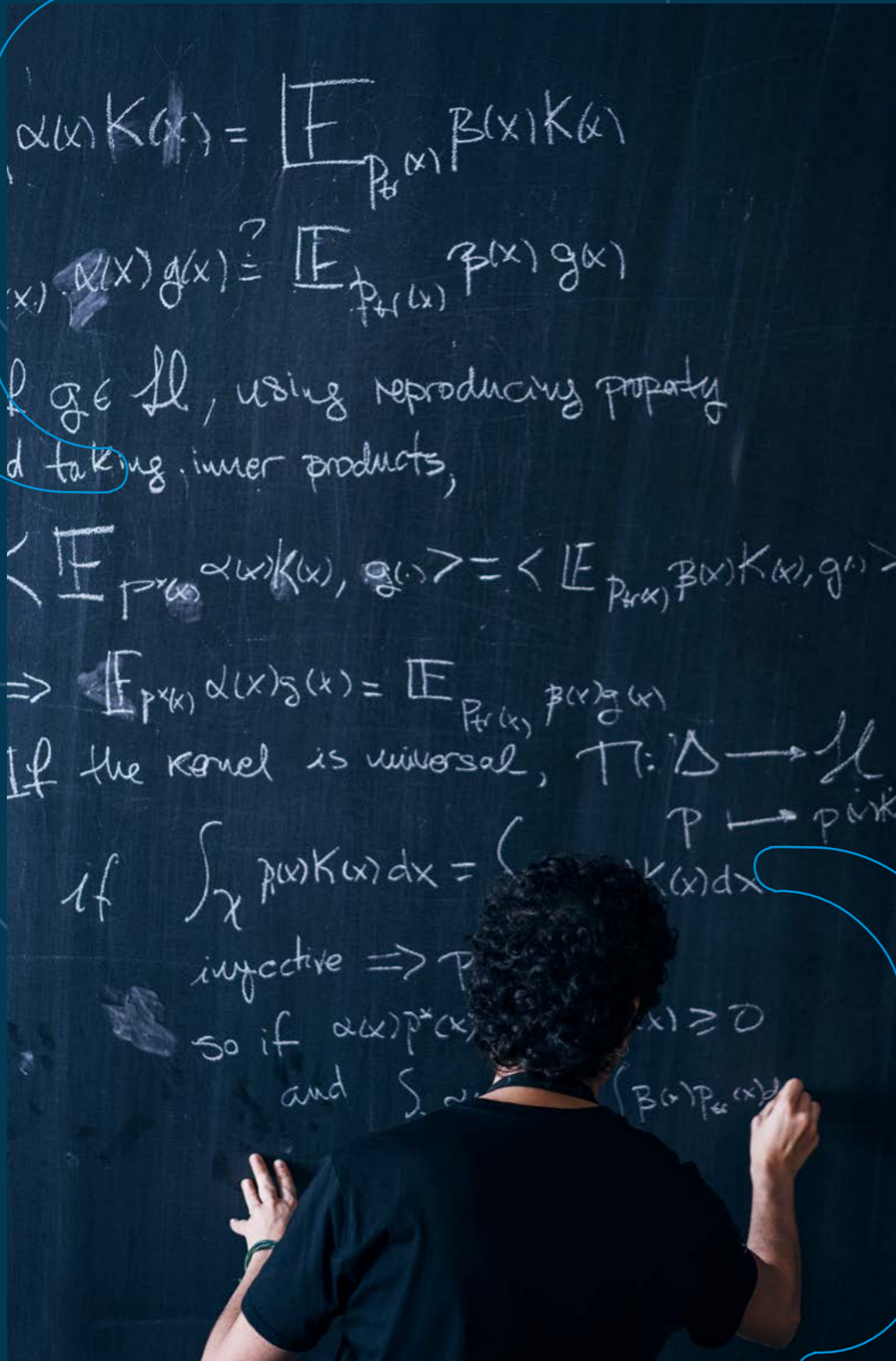


Dr. Marc Schoenauer

INIRIA Saclay Île-de-France
France



04. Funding



You can check BCAM's research projects in [our website](#)



101120763

TANGO - It takes two to tango: a synergistic approach to human-machine decision making (Horizon - RIA)

Funded by: A HUMAN-CENTRED AND ETHICAL DEVELOPMENT OF DIGITAL AND INDUSTRIAL TECHNOLOGIES 2022 (HORIZON-CL4-2022-HUMAN-02)
Duration: 2023/10 – 2027/09
PI: Prof. Quadrianto, N.

AI possesses the potential to enhance decision-making, mitigate bias and decrease cognitive overload. Nevertheless, instilling trust in the reliability of AI remains essential. The EU-funded TANGO project will forge hybrid decision support systems that harmonise human and machine values and objectives, fortifying Europe's prominence in human-centric AI. It will formulate a cognitive theory of mutual comprehension and hybrid decision-making, create explainable AIs attuned to cognition, and facilitate a 'human-in-the-loop' co-evolution of human decision-making and machine learning models. TANGO is set to execute four impactful use cases: providing support to women during pregnancy and postpartum, aiding surgical teams, assisting loan officers and applicants in credit lending assessments, and guiding public policymakers in devising incentives and distributing funds.

About PI

Novi Quadrianto is currently a Professor of Machine Learning at the University of Sussex, UK. Prior to Sussex, Novi was a Newton International Fellow of the Royal Society and the British Academy at the Machine Learning Group in the Department of Engineering, University of Cambridge. Novi received his Ph.D. in Computer Science from the Australian National University, Canberra, Australia in 2012. In 2019, Novi was awarded a European Research Council ERC Starting Grant for a project on developing Bayesian models and algorithms for fairness and transparency (BayesianGDPR). Since March 2021, Novi also leads a BCAM Severo Ochoa Strategic Lab on Trustworthy Machine Learning in Spain. Since July 2022, Novi holds an Adjunct position at Monash University in Indonesia.



851538

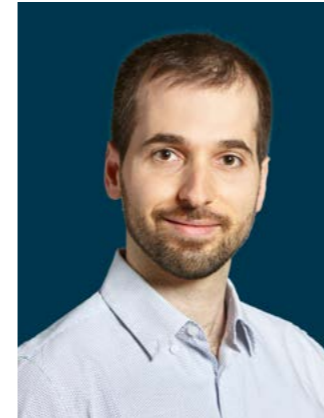
Bayesian GDPR - Bayesian Models and Algorithms for Fairness and Transparency (Horizon 2020)

Funded by: ERCEA Starting Grant
Duration: 2020/04 – 2025/09
PI: Prof. Quadrianto, N

The General Data Protection Regulation (GDPR) states data should be processed lawfully, fairly and transparently. With this in mind, the EU-funded BayesianGDPR project aims to integrate the legal non-discriminatory principles of GDPR into automated machine-learning systems in a transparent manner. It will do so by using a novel Bayesian approach to model all sources of uncertainty, and taking into account feedback from humans and future consequences of their outputs. BayesianGDPR will provide organisations that rely on machine learning technologies with concrete tools allowing them compliance with the non-discriminatory principles of GDPR and similar laws. The project's achievements will have an impact on computational law research and its integration into mainstream legal practice. It will also promote public confidence in machine learning systems.

About PI

Novi Quadrianto is currently a Professor of Machine Learning at the University of Sussex, UK. Prior to Sussex, Novi was a Newton International Fellow of the Royal Society and the British Academy at the Machine Learning Group in the Department of Engineering, University of Cambridge. Novi received his Ph.D. in Computer Science from the Australian National University, Canberra, Australia in 2012. In 2019, Novi was awarded a European Research Council ERC Starting Grant for a project on developing Bayesian models and algorithms for fairness and transparency (BayesianGDPR). Since March 2021, Novi also leads a BCAM Severo Ochoa Strategic Lab on Trustworthy Machine Learning in Spain. Since July 2022, Novi holds an Adjunct position at Monash University in Indonesia.



948029

StableIF - Stable interfaces: phase transitions, minimal surfaces, and free boundaries (Horizon 2020)

Funded by: ERCEA Starting Grant
Duration: 2021/01 – 2025/12
PI: Prof. Serra, J.

The theory of nonlinear elliptic partial differential equations (PDE) experienced significant development in the latter half of the 20th century, primarily driven by the mathematical analysis of physical models involving “interfaces.” These interfaces manifest as minimal surfaces, phase transitions, free boundaries, etc., depending on the specific model. These models hold great importance in practical applications, and their study involves interdisciplinary methods, making them intriguing from a pure mathematics perspective.

The Allen-Cahn equation, a simple semilinear PDE featuring an interface, initially proposed as a model for metal alloys, gained mathematical prominence due to its profound connections with the minimal surface equation and other essential PDE. It is closely linked to various models such as the Cahn-Hilliard equation, Peierls-Nabarro equation, and Ginzburg-Landau theory.

While considerable progress has been made in understanding the structure of energy minimizers for these models, little is known about the structure of stable solutions—minimizers with respect to small perturbations. Since stable solutions represent observable phenomena in nature, unraveling their structure becomes a fundamental question. Despite being a challenging mathematical problem, recent advancements and analysis tools provide an excellent opportunity to delve into the understanding of stable interfaces. In essence, the ambitious goal of this ERC project is to comprehensively “understand stable interfaces,” leveraging the progress in mathematical tools and knowledge amassed over the last few decades.

About PI

Joaquim Serra is an Assistant Professor of Mathematics at ETH Zurich. His research is focused on Elliptic Partial Differential Equations. More precisely on, stable interfaces (phase transitions and minimal surfaces), free boundaries (the singular sets in the obstacle problem and the Stefan problem), elliptic and parabolic integro-differential equations (integration by part type identities with singular boundary terms, regularity for fully nonlinear equations) and reaction-diffusion equations, isoperimetric problems.



101113946

OpenSuperQPlus - Open Superconducting Quantum Computers (HORIZON-CL4-2021-DIGITAL-EMERGING-02)

Funded by: HORIZON - CL4 - 2022 - QUANTUM - 01 - SGA

Duration: 2023/03 – 2026/08

PI: Dr. Sanz, M.

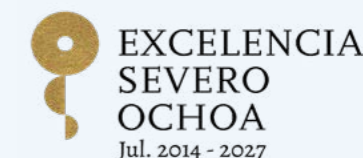
The OpenSuperQplus consortium is a structured partnership aiming at large-scale European quantum computers in the superconducting platform. It proposes and implements a set of roadmaps covering the complete technology stack including quantum hardware, enabling hard- and software, engineering, and an application-driven test suite. It will implement and guide two specific grant agreements (SGAs), aiming at 100 and 1000 qubits with high fidelity, respectively. Grown out of the ramp-up project OpenSuperQ, it brings together a community of excellent academic groups, RTOs, and companies of various sizes spread over Europe, and that includes widening countries. Industrial partners allow to commercialize components, enabling technologies as well as full machines. Its scientific focus is on high coherence, which is crucial to reach the break-even point of quantum advantage in NISQ and reaching out to fault tolerance. Beyond the SGAs, OpenSuperQplus will collaborate with many other Flagship projects, contribute to standardization through CEN/CENELEC, and form a sustainable partnership in the form of a professional organization.

About PI

Mikel Sanz leads the group Quantum Computation and Architectures at the Department of Physical Chemistry since 2018. In 2020, he was awarded with an Ikerbasque Fellow position and, since 2021, he is also Ramón y Cajal Researcher at UPV/EHU. He has recently joined the Basque Center for Applied Mathematics (BCAM) to foster the research in quantum technologies.

One of his main research lines is quantum computing, particularly focused on the design of quantum algorithms, with special attention to the study of their mathematical properties and their applications to industrial use cases. Additionally, he is pioneer in the development of noisieresilient alternative paradigms of quantum computation, such as digital-analog quantum computation, as well as the co-design of quantum architectures. Other principal research lines are secure quantum communications between satellites and quantum metrology, in particular, the theory of quantum parameter estimation. Finally, he studies the role of algebraic geometry as a natural language to describe quantum entanglement, connecting it with potential applications in quantum technologies.

Distinctions and Public Funding Institutions



HR EXCELLENCE IN RESEARCH



05. Scientific activities

Throughout 2023, BCAM has actively engaged in organizing and hosting a range of scientific activities. The center has conducted 10 specialized courses, including 6 BCAM Courses and 4 BCAM Severo Ochoa Courses, taught by its own researchers as well as experts from other institutions. These courses are designed to enhance the expertise of PhD students and research personnel.

In collaboration with the University of the Basque Country (UPV/EHU), BCAM has co-hosted biannual math colloquiums and facilitated 45 joint sessions in Analysis and PDE, fostering a deeper understanding in these fields.

BCAM also promotes the exchange of knowledge through its seminar program, contributing to the broader academic and industrial community.

Additionally, BCAM researchers travel widely for collaboration and attend various international conferences and workshops to both share and augment their knowledge, as well as to forge new professional ties.

During 2023, many scientific activities have been organized by BCAM. The topics cover all areas of knowledge of the centre:

7th annual Meeting of the Spanish Network for Algebraic Geometry and Singularity Theory

The Algebraic Geometry and Singularities are areas of mathematics with a strong implementation in Spain. The RGAS network is made up of 13 nodes where Algebraic Geometry and Theory of Singularities are addressed from diverse points of view and with very different tools. These points of view and tools are undoubtedly complementary.

The main objectives of the RGA network are (1) to strengthen our areas of specialization and to expand them in the most relevant directions of current research, (2) to maintain and improve our international presence, and (3) to take advantage of our internal synergies and to generate international collaboration that helps us maintain a research and training environment of the first international level.



Several young researchers and senior researchers of the RGAS Network has gathered for its 7th annual meeting.

BIDAS 5: Fifth Bilbao Data Science Workshop

Data Science is a multifaceted discipline uniting mathematics, statistics, and computer science to unravel insights from diverse data forms. In the age of digitalization, challenges across research domains necessitate innovative approaches to analysis and algorithms. The BiDAS workshop (Bilbao workshop in Data Science) serves as a forum for professionals spanning applied mathematics, computer science, statistics, and various scientific fields. It fosters collaboration among ecologists, biologists, economists, and more, encouraging information exchange and interaction. Notably, the event prioritizes PhD students and Postdocs, offering a platform to showcase their research alongside esteemed international speakers, fostering a vibrant community of knowledge-sharing and networking.

This will be the fifth edition of BiDAS at BCAM headquarters. A total of five sessions were organized during a two-day workshop. Each session featured a keynote speaker from internationally renowned European institutions delivering a one-hour talk on a specific topic, followed by two 30-minute invited talks. The scientific committee actively promoted early-stage researchers, including Master's and Ph.D. students, as well as postdocs, to submit brief abstracts for poster presentations.



Harmonic Analysis and Differential Equations: new questions and challenges

The workshop “Harmonic Analysis and Differential Equations: new questions and challenges” honours the distinguished career of Prof. Luis Vega by bringing together leading mathematicians working in Partial Differential Equations and Harmonic Analysis to learn about the recent developments and future directions in these and related areas.

Matematikhariak: STEAM week of BCAM

Matematikhariak started in 2023 at the Basque Centre for Applied Mathematics - BCAM as a new programme based on the dissemination of STEAM sciences. On this first edition, BCAM took part in BCAM-Naukas 2023, Pi Day, received the visit of the Bizilabe programme at the centre and participated in the Parekoen Topaketa activity, both promoted by Elhuyar Zientzia.

matemat*kh*ar*ak*

5th BCAM-UPV/EHU summer school on harmonic analysis and PDEs: Sphere packing

The 5th edition of the BCAM-UPV/EHU summer school on harmonic analysis and PDEs, focusing on Sphere Packing, was organized by the Basque Center for Applied Mathematics (BCAM) and UPV/EHU. The event took place spanning two locations: BCAM and the Leioa campus of UPV/EHU.

The summer school, dedicated to sphere packing, comprised three mini-courses and working groups addressing specific topics related to these courses. Felipe Gonçalves (IMPA), Philippe Moustrou (University of Toulouse), and Danylo Radchenko (University of Lille) were invited to deliver the mini-courses and coordinate the learning activities.

The discussed topics included Sign uncertainty, interpolation, and quasicrystals, Optimization methods for sphere packing problems, and Modular forms and their applications to sphere packings.



14th Conference on Dynamical Systems Applied to Biology and Natural Sciences

The International Conference on Dynamical Systems Applied to Biology and Natural Sciences – DSABNS is a well established International Scientific event that has been organized since 2010, every year during the month of February. The program includes Public Lectures providing a public forum for academic researchers from diverse disciplinary backgrounds; Plenary talks which are scheduled to open and to close the scientific program (morning and afternoon); Invited talks are meant to provide context for a parallel session which is filled with Contributed Talks given by the conference participants. The conference programme covers research topics in scientific areas such as population dynamics, eco-epidemiology, epidemiology of infectious diseases, molecular and antigenic evolution and methodological topics in the natural sciences and mathematics. Poster Sessions are also part of the conference which also counts with a Book of Abstracts with ISBN, published at the end of the event.

06. Highlighted publications

Authors:
Fernandez-Navamuel, A.
Pardo, D.
Magalhães, F.
Zamora-Sánchez, D.
Omella, A.J.
García-Sánchez, D.

Bridge damage identification under varying environmental and operational conditions combining Deep Learning and numerical simulations

Research Line: Mathematical Design, Modelling And Simulations MATHDES

This work proposes a novel supervised learning approach to identify damage in operating bridge structures. We introduce the effect of environmental and operational conditions into the synthetic damage scenarios employed for training a Deep Neural Network by means of a Gaussian Mixture clustering technique that selects representative measurements. The synthetic and experimental data feed two Deep Neural Networks that assess the structural condition regarding damage severity and location. We demonstrate the applicability with a real case study: Infante Dom Henrique bridge.

Mechanical Systems and Signal Processing, Volume 200, 2023, 110471, ISSN 0888-3270

Authors:
Moreno Chaparro, N.
Ellero, M.

Generalized Lagrangian Heterogeneous Multiscale Modeling of Complex Fluids

Research Area: Computational Mathematics

Research Line: CFD Modelling and Simulation CFDMS

In this work we propose a novel fully Lagrangian heterogeneous multiscale method (LHMM) for modeling complex fluids across large spatio/temporal scales like polymeric solutions and multiphase systems. LHMM discretizes Navier–Stokes equations via SDPD, bypassing constitutive relations, and handles thermal fluctuations consistently as particle size decreases. Validated with diverse flows and fluids, LHMM flexibly models microscale complexities in several microstructured fluids, effectively capturing stress transitions from micro to macro scales, enhancing fluid response continuity, and linking macroscale fluid mechanics with microscale memory effects in complex liquids.

Journal of Fluid Mechanics, 2023, 969, A2.

Authors:
Backman, T.W.H.
Schenk, C.
Radivojevic, T.
Ando, D.
Singh, J.
Czajka, J. J.
Costello, Z.
Keasling, J.D.
Tang, Y.
Akhmatskaya, E.
García Martín, H.

BayFlux: A Bayesian Method to Quantify Metabolic Fluxes and their Uncertainty at the Genome Scale

Research Area: Mathematical Modelling with Multidisciplinary Applications – M3A

Research Line: Modelling and Simulation in Life and Materials Sciences MSLMSS

We present a method for flux space sampling through Bayesian inference (BayFlux) that identifies the full distribution of fluxes compatible with experimental data for a comprehensive genome-scale model. With BayFlux, we found that the genome-scale model of metabolism produces reduced uncertainty compared to small core metabolic models commonly used in metabolic flux analysis. Based on BayFlux, we developed and evaluated two novel methods to predict the biological results of a gene knockout, that improve on the traditional methods by quantifying prediction uncertainty.

PLOS Computational Biology, 2023, 19 (11): e1011111

Authors:
Stollenwerk, N.
Estadilla, C.D.S.
Mar, J.
Bidaurrezaga Van-Dierdonck, J.
Ibarondo, O.
Blasco-Aguado, R.
Aguilar, M.

The effect of mixed vaccination rollout strategy: A modelling study

Research Area: Mathematical Modelling with Multidisciplinary Applications – M3A

Research Line: Mathematical and Theoretical Biology MTB

The research assesses the impact of the early COVID-19 vaccination phase using an extended SHAR model. Two vaccine types were analyzed: one preventing severe disease and another targeting both severe disease and infection. Vaccine efficacy, derived from trials, considered variations between one and two doses. In the Basque Country, a decrease in hospitalized cases was observed five months post-rollout, aligning well with model predictions in June 2021. The findings emphasize the effectiveness of COVID-19 vaccines in preventing both severe cases and infection.

Infectious Disease Modelling, 2023, 8, 2, 318-340

Authors:
Sefati, N.
Esmailpour, T.
Salari, V.*
Zarifkar, A.
Dehghani, F.
Ghaffari, M. K.
Zadeh-Haghighi, H.
Császár, N.
Bókkon, I.
Rodrigues, S.* and Oblak, D.*
(*: co-corresponding author)

Monitoring Alzheimer's disease via ultraweak photon emission

Research Area: Mathematical Modelling with Multidisciplinary Applications – M3A

Research Line: Mathematical, Computational and Experimental neuroscience MCEN

We detected ultraweak photon emission (UPE) from the hippocampus of male rat brains and found significant correlations between Alzheimer's disease (AD), memory decline, oxidative stress, and UPE intensity. This opens up novel methods for screening, detecting, diagnosing, and classifying neurodegenerative diseases, e.g. AD. We propose to develop a minimally invasive brain-computer interface (BCI) photonic chip for monitoring and diagnosing AD, with high spatiotemporal brain activity resolution.

iScience, 2024, 27, 1

Authors:
Ibarrondo, R.
Gatti, G.
Sanz, M.

Quantum Genetic Algorithm with Individuals in Multiple Registers

Research Area: Mathematical Physics - MP

Research Line: Quantum Mechanics - QM

We propose a quantum genetic algorithm with individuals in independent registers, incorporating population-based search, selection, crossover, and mutation. Comparing quantum cloning machines in the crossover, the biomimetic cloning shows faster convergence, while the Buzek-Hillery machine exhibits superior final populations. A mutation subroutine has a minor impact on average performance. Quantum channel analysis shows exponential convergence and allows predicting the convergence ratio, offering a tool for formal proofs in non-unitary iteration-based algorithms.

IEEE Transactions on Evolutionary Computation, 2023, 1

Authors:
Pagnini G.
Runfola C.

Mellin definition of the fractional Laplacian

Research Area: Mathematical Physics - MP

Research Line: Statistical Physics - SP

It is known that at least ten equivalent definitions of the fractional Laplacian exist in an unbounded domain. Here we derive a further equivalent definition that is based on the Mellin transform. The one-dimensional case is also considered, such that the Mellin transform of the Riesz fractional derivative is established. This one-dimensional result corrects an existing formula in literature. Further results for the Riesz fractional derivative are obtained, in particular its relation with the Caputo and the Riemann-Liouville fractional derivatives.

Fractional Calculus and Applied Analysis, 2023, 26, 2101-2117

Authors:
Fernandez de Bobadilla, J.
Pallares, I.
Saito, M.

Hodge Modules and Cobordism Classes

Research Area: Mathematical Physics - MP

Research Line: Singularity Theory and Algebraic Geometry - STAG

We show that the cobordism class of a polarization of Hodge module defines a natural transformation from the Grothendieck group of Hodge modules to the cobordism group of self-dual bounded complexes with real coefficients and constructible cohomology sheaves in a compatible way with push-forward by proper morphisms. This implies a new proof of the well-definedness of the natural transformation from the Grothendieck group of varieties over a given variety to the above cobordism group (with real coefficients). As a corollary, we get a slight extension of a conjecture of Brasselet, Schürmann and Yokura, showing that in the \mathbb{Q} -homologically isolated singularity case, the homology L-class which is the specialization of the Hirzebruch class coincides with the intersection complex L-class defined by Goresky, MacPherson, and others if and only if the sum of the reduced modified Euler–Hodge signatures of the stalks of the shifted intersection complex vanishes. Here Hodge signature uses a polarization of Hodge structure, and it does not seem easy to define it by a purely topological method.

Journal of the European Mathematical Society, 2023

Authors:
Genovese, G.
Lucà, R.
Tzvetkov, N.

Transport of Gaussian measures with exponential cut-off for Hamiltonian PDEs

Research Area: Analysis of Partial Differential Equations - APDE

Research Line: Linear and Non-Linear Waves - WAVE

We show that introducing an exponential cut-off on a suitable Sobolev norm facilitates the proof of quasi-invariance of Gaussian measures with respect to Hamiltonian PDE flows and allows us to establish the exact Jacobi formula for the density. We exploit this idea in two different contexts, namely the periodic fractional Benjamin-Bona-Mahony equation and the periodic one dimensional quintic defocusing nonlinear Schrödinger equation.

Journal d'Analyse Mathématique, 2023, 150, 737-787

Authors:
Feireisl, E.
Roy, A.
Zarnescu, A.

On the motion of a large number of small rigid bodies in a viscous incompressible fluid

Research Area: Analysis of Partial Differential Equations - APDE

Research Line: Applied Analysis - AA

We consider the motion of several rigid bodies depending on a small parameter and which are immersed in a viscous incompressible fluid. We show the fluid flow is not influenced by the presence of the infinitely many bodies in the asymptotic limit of the vanishing small parameter and when the number of bodies increases asymptotically (in a suitable manner depending on the small parameter). The result depends solely on the geometry of the bodies and is independent of their mass densities. Collisions are allowed and the initial data are arbitrary with finite energy.

Journal de Mathématiques Pures et Appliquées, 2023, 9, 175, 216-236

Authors:
Ionescu, A.D.
Magyar, A.
Mirek, M.
Szarek, T.Z.

Polynomial averages and pointwise ergodic theorems on nilpotent groups

Research Area: Analysis of Partial Differential Equations - APDE

Research Line: Harmonic Analysis - HA

The authors establish pointwise almost everywhere convergence for ergodic averages along polynomial sequences in nilpotent groups of step two of measure-preserving transformations on \mathbb{T} -finite measure spaces. They also establish corresponding maximal inequalities on L^p for $1 < p \leq \infty$ and ρ -variational inequalities on L^2 for $2 < \rho < \infty$. This gives an affirmative answer to the Furstenberg-Bergelson-Leibman conjecture in the linear case for all polynomial ergodic averages in discrete nilpotent groups of step two. The proof is based on almost-orthogonality techniques that go far beyond Fourier transform tools, which are not available in the non-commutative, nilpotent setting. In particular, they develop what they call a nilpotent circle method that allows us to adapt some of the ideas of the classical circle method to the setting of nilpotent groups.

Inventiones Mathematicae, 2023, 231, 3, 1023–1140.

Authors:
Alvarez, V.
Mazuelas, S.
Lozano, J.A.

Minimax Forward and Backward Learning of Evolving Tasks with Performance Guarantees

Research Area: Data Science - DS

Research Line: Machine Learning - ML

The paper presents incremental learning methods that effectively exploit forward and backward learning and account for evolving tasks. In addition, the paper analytically characterizes the increase in effective sample size achieved by the proposed techniques. The proposed methodology for incremental learning with evolving tasks can lead to techniques that further approach the humans' ability to learn from few examples and to continuously improve on tasks that arrive over time.

Advances in Neural Information Systems (NeurIPS), 2023, 36

Authors:
Rodríguez-Álvarez, M.X.
Durbán, M.
Eilers, P. H. C.
Lee, D.-J.
Gonzalez, F.

Multidimensional Adaptive P-Splines with Application to Neurons' Activity Studies

Research Area: Data Science - DS

Research Line: Applied Statistics - AS

This study introduces an advanced anisotropic locally adaptive P-spline model for detailed 2D and 3D spatiotemporal analysis of visual neurons' receptive fields. Leveraging the SOP method, it enhances computational efficiency and addresses the need for high precision in mapping noisy RF maps with sharp transitions. It fills existing gaps in adaptive P-splines for multidimensional data, offering significant improvements in computational speed and accuracy, validated through simulations against alternative methods.

Biometrics, 2023, 79, 3, 1972-1985

Authors:
Ahrari, A.
Elsayed, S.
Sarker, R.
Essam, D.
Coello Coello, C.A.

Revisiting Implicit and Explicit Averaging for Noisy Optimization

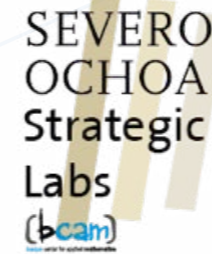
Research Area: Data Science - DS

Research Line: Combinatorial Optimization - CO

Explicit and implicit averaging are two well-known strategies for noisy optimization. Both strategies can counteract the disruptive effect of noise; however, a critical question remains: which one is more efficient? This question has been raised in many studies, with conflicting preferences and, in some cases, findings. Nevertheless, theoretical findings on the noisy sphere problem with additive Gaussian noise supports the superiority of implicit averaging, which may have had a strong impact on the preference of implicit averaging in more recent evolutionary methods for noisy optimization. This study speculates that the analytically supported superiority of implicit averaging relies on specific features of the noisy sphere problem with additive noise, which cannot be generalized to other problems. It enumerates these features and designs controlled numerical experiments to investigate this potential reliance. Each experiment gradually suppresses one specific feature, and the progress rate is numerically calculated for different values of the sample size given a fixed evaluation budget. Our empirical results indicate that for a wide range of noise strength and evaluation budget per iteration, the more these specific features are suppressed, the more the optimal averaging strategy deviates from implicit toward explicit averaging, which confirms our speculations. Consequently, the optimal sample size, which is regarded as the tradeoff between implicit and explicit averaging, depends on the problem characteristics and should be learned during optimization for maximum efficiency.

IEEE Transactions on Evolutionary Computation, 2023, 27, 5, 1250--1259

07. Severo Ochoa Joint Research Lab Program



This initiative is part of the actions promoted by BCAM thanks to the accreditation of "Severo Ochoa Centre of Excellence" granted by the Ministry of Science and Innovation through the State Research Agency and that BCAM has for the period 2023-2027.

1. Strengthen contacts within the international scientific community.
2. To provide specialized training to the members of the centre.
3. To promote collaborative research on hot topics such as machine learning methods and PDEs, Elliptic and Dispersive PDEs and their relation with Geometry and Fluid Mechanics, and thus strengthen the centre's research areas and generate synergies.
4. To contribute to BCAM projects on mathematical modelling applied to health.
5. Explore the connection between pure/applied mathematics and new research topics in collaboration with BCAM research areas.

This program highlights the importance of international collaboration between research centres and universities, as well as the strengthening that this can mean for the centre's lines of research and its international positioning. The agreement will materialize through different activities such as the joint supervision of postdoctoral researchers or visits to the centre and joint participation in scientific activit

Let's write together Mathematics for the Future
 Idatz ditzagun elkarrekin etorkizuneko matematika
 Escribamos juntos las matemáticas del futuro

$$f(x,t|\bar{x}) = \begin{cases} \int_0^\infty G(x-\bar{x}-l\hat{n}_w;t)q(l;t)dl, & \hat{n}_w \geq 0 \\ G(x-\bar{x};t), & \text{otherwise} \end{cases}$$

$$G(x-\bar{x};t) = \frac{1}{\sqrt{2\pi s(t)}} \exp\left\{-\frac{(x-\bar{x})^2 + (y-\bar{y})^2}{2s(t)}\right\}$$

and, $q(l;t) = \frac{1}{\sqrt{2\pi} s(t) l} \exp\left\{-\frac{(\ln l - \mu(t))^2}{2s(t)^2}\right\}$

where $\mu(t) = \langle \ln l \rangle$, $s(t) = \langle (\ln l - \mu(t))^2 \rangle$

BCAM Severo Ochoa Strategic Labs

Joint Research Labs



Joint Research Lab U. Sussex

The “BCAM Severo Ochoa Strategic Lab on Trustworthy Machine Learning” is held together with Prof. Novi Quadrianto at the University of Sussex and co-led by Jose A. Lozan, Scientific Director of BCAM and coordinator of the Data Science and Artificial Intelligence research area.



Joint Research Lab U. Oxford

The “BCAM Severo Ochoa Strategic Lab on Modelling with Partial Differential Equations in Mathematical Biology” is held together with Prof. Jose Antonio Carrillo at Mathematical Institute, Oxford University and co-led by Prof. Elena Akhmatskaya, Ikerbasque Professor at BCAM who coordinates the area of Mathematical Modelling with Multidisciplinary Applications.



Joint Research Lab ETH Zurich

The “BCAM Severo Ochoa Strategic Lab on Analysis of PDEs” is held in collaboration with Prof. Joaquim Serra from ETH Zurich. The laboratory is co-led by Prof. Luis Vega, coordinator of the APDE research area.



Joint Research Lab Rényi Institute and KU Leuven

The “BCAM Severo Ochoa Strategic Lab on Singularity Theory” is held together with Prof. Andras Némethi (Rényi Institute Budapest), Prof. Duco van Straten (Mainz University) Prof. Nero Budur (KU Leuven). The laboratory is co-led by Prof. Javier Fernández de Bobadilla, Ikerbasque Professor at BCAM and research area coordinator of Mathematical Physics.



Joint Research Laboratory on Offshore Renewable Energy (Tecnalia-UPV/EHU-BCAM)

The Joint Research Laboratory on Offshore Renewable Energy is composed of researchers from TECNALIA, UPV/EHU and BCAM.



Joint Research Laboratory on Artificial Intelligence (Tecnalia-UPV/EHU-BCAM)

The Joint Research Lab team is composed of fully collaborative and open-minded researchers. The research areas of the JRL-AI are: Time Series Analysis, Stream Learning, Optimization, Lifelong Machine Learning, Adversarial Machine Learning.



Transmath Transborder Laboratory for Mathematics and its Applications

The Laboratories for Trans-border Cooperation (LTCs) are a formula for collaboration that have been developed since 2015 in the frame of the Campus Euskampus-Bordeaux. TRANSMATH is a project created in 2017 for mathematics to work in the specific subject of: 1) cutting edge research in the classical fields of mathematics: ge, etru, algebra, analysis of PDEs, etc., 2) modeling and simulation, in particular in the applications to environment and health related issues, and 3) data science.



08. Knowledge Transfer Unit

The aim of BCAM Knowledge Transfer Unit is structured around four main objectives:

1. Multidisciplinary applied research projects.
2. Mathematical challenges based of the real life.
3. Scientific vocations, training, transfer activities and contribution to the improvement of mathematics social perception.
4. Policy makers advice.

One of BCAM's most important missions is to spread knowledge and technology in the industry and the society in general.

It is critical for the Basque Center for Applied Mathematics to transfer the obtained research results to sectors as biosciences, health, energy, advanced manufacturing, telecommunications and transport, including local, national and international entities.

For that purpose, BCAM offers expertise in many research fields to SMEs and large industrial groups, and supports the creation of new companies.

Collaboration models

Strategic partnerships

Collaborative R&D&I projects

Joint positions / research teams

Supervision of Master and PhD Students

Training courses

Organization of dissemination activities

Private funding ongoing projects



Project: Early prognosis of COVID-19 infections via Machine Learning.

Goal: To develop supervised learning techniques that use health data to predict COVID-19 infections' future severity.



Project: Goal-directed behavior and the origin of life.

Goal: To investigate the hypothesis that certain types of nonliving or proto-living systems can exhibit minimal forms of goal-directed behavior.



Project: Bunkering procedure optimization.

Goal: To find the optimal schedule for cargo ships and the sequence of each refuelling procedure.

Joint positions and industrial doctorates



09. BCAM in the media

90

APPEARANCES

2

Print Media

3

TV

9

Radio

27

Blogs + websites

49

Online press

To make BCAM's work known to society, the appearance in the media helps the message reach more people. This year we can highlight the following appearances:

15th Anniversary

In November and December, the BERC - BCAM, BC3 and BCBL centers celebrated their 15th anniversary.

This milestone was celebrated with enthusiasm and recognition. The first appointment was an institutional event at the Iberdrola Tower chaired by Jokin Bildarratz, Minister of Education of the Basque Government.

Then, in December, the celebration was extended to the public with two participatory days in which schoolchildren and citizens enjoyed activities focused on mathematics, climate change, and neuroscience in Bilbao and Donostia.

BCAM - Naukas Pi day

The event takes place the 14 March with different activities for the general public and with the aim of bringing mathematics closer to them and to make known, among other things, the properties and applications of the number Pi in everyday life.

Luis Vega awarded with the RSME Medal 2023

Luis Vega, principal investigator of the Severo Ochoa accreditation at BCAM and professor in the Department of Mathematics at the UPV/EHU, was awarded the RSME Medal 2023 in July. With this distinction the scientific society expresses the public recognition of the mathematical community to people who have stood out for "their relevant and continuous contributions in mathematical fields, such as education, research, transfer and dissemination, among others".

Paula Gordaliza Pastor, postdoctoral researcher at BCAM, awarded with one of the Vicent Caselles mathematical research prizes

Paula Gordaliza was one of the six young researchers awarded the Vicent Caselles Mathematical Research Prize 2023, awarded by the Spanish Royal Mathematical Society and the BBVA Foundation. This award recognises creativity, originality and achievement in the field of mathematics research in the early years of the scientific profession.

The jury of the awards highlighted the aim of the BCAM researcher's thesis, which focuses on correcting the biases that exist in artificial intelligence (AI) algorithms.

10. Gender Balance Actions



BCAM is dedicated to integrating a gender lens into all its endeavors, striving to eradicate disparities and advance genuine equality between genders on a global scale.

In pursuit of this mission, BCAM engages in various initiatives aimed at advancing women's contributions in research and cultivating the enthusiasm of young girls for STEM careers. In 2023, BCAM actively participated in the following endeavor:

BCAM Gender Equality Corner

BCAM Equality Gender Corner. This space gathers all the information regarding gender equality at BCAM. We have set up a shelf where the Equality Plan 2022-2026 is available for everyone, together with books on women in science.

BCAM Women Scientific Seminars

BCAM continued the "BCAM Women Scientific Seminars" initiative. This proposal is aimed to give visibility to the work of female mathematicians in the dissemination of their research work.

Women for Africa

In 2023, BCAM continued to contribute to the "Women for Africa" program. The FMxA program has the aim to promote African women's leadership in scientific research and technology transfer and to foster the capacity of the research centres in their home countries. Dr. Maira Aguiar, one of our researchers and Group Leader of the Mathematical and Theoretical Biology Research Line hosted Dr. Amira Kebir, who is an Associate Professor at the Institut Préparatoire Aux Etudes d'Ingénieurs at the University of Tunis.

11 F

The talk 'Scientists of yesterday and today' was celebrated on 17 February at the Bidebarrieta Kulturgunea. Six women scientists working in research centres in Bizkaia will talk about the research they are involved in and pay tribute to some of the great women scientists in history by telling the story of their fascinating lives and scientific contributions. Among the six participants was BCAM PHD student Lore Zumeta, who in addition to presenting her research, talked about Florence Nightingale.

Talks in schools

PHD students Ainhize Barrainkua and Margarida Moragues presented their work and their personal experience in the world of research to students from different schools.

Jone Renteria, BCAM's Research Technician, visited her old school in order to share her experience as a researcher both in the U.S. and here.

Emakumeak Zientzian

BCAM was part of Emakumeak Zientzian. This initiative seeks to make the activity of women in science visible, to break with the typically male roles attributed to scientific-technical activities, and to encourage girls and adolescents to choose scientific careers.

Women at BCAM

Leire Garmendia

PHD student at BCAM

I decided to study mathematics and then specialize in statistics because it allows me to understand many aspects of everyday life. My advice to fellow girls is to choose what you're genuinely excited about, not what others think you should do. Science careers may be tough, but with perseverance, you can conquer any challenge. Dive into what excites you, and you'll discover science is a journey full of growth and great times.



Onintze Zaballa

Postdoctoral Fellow at BCAM

What inspired me to pursue a career in science was the curiosity and the challenge to solve new mathematical problems that could also make a positive impact on society. To a young female researcher, I would tell her to pursue that curiosity with passion and persistence, even if it may seem daunting at times. Surround herself with supportive people, and believe in her ability to make a meaningful research contribution with her unique perspective.



Ana Fernandez-Navamuel del Olmo

Postdoctoral Researcher at BCAM and Tecnalia

My inspiration to pursue a career in science stems from a profound curiosity and desire to learn about the world and its many interesting phenomena, combined with a need to impact society positively. However, I believe the most honest motivation driving my decision was simply a search for happiness. Since high school, I have really enjoyed math lessons, and that is something I wanted to preserve for my professional life. If I were to give advice, try to do what makes you happy, even if it seems simple or even if it seems very hard, because the key to success is waking up every morning with an honest smile, ready to face the challenges of today

Luz Roncal

Ikerbasque Research Associate at BCAM

There was not only one 'motivational woman scientist', there were many, and there still are. I know some of them very well because we've met many times in conferences over the years, or because they encouraged me when I was a fearful student. Or because they gave me advice, or congratulated me when it was time for brief success; or because they were very few in their time, maybe the only ones, and this was remarkable. Others are mathematicians who surround me today; and others I never met, beyond being a name in outstanding papers that have been inspiring for my research. For those who come after me: go ahead with determination, effort, daring and sacrifice, do not be defeated by circumstances, do not let anyone silence your opinion. Continue your work without stridency, but with constancy. In time your work will speak for you.



11. Networks and agreements

Being a multidisciplinary centre, collaboration between institutions and researchers is fundamental for the Basque Center for Applied Mathematics. Currently, BCAM belongs to some of the most important national and international networks in its field. We organized our participation in these networks and consortiums in the following way:

1. Strategic & institutional networks



ERCOM
European Research Centers on Mathematics
www.euro-math-soc.eu/committee/ercom



EWM
European Women in Mathematics
www.europeanwomeninmaths.org



EU-MATHS-IN
European Service Network of Mathematics for Industry and Innovation
www.eu-maths-in.eu



SOMMA
The 'Severo Ochoa' Centers and 'Maria de Maeztu' Units of Excellence Alliance
www.somma.es



REM
Strategic Network in Mathematics
www.institucionales.us.es/remimus

2. Joint research labs & platforms



LTC-TRANSMATH
Joint Transborder Laboratory in Mathematics
www.transmath.org/en



Joint Research Lab on Offshore Renewable Energy (JRL-ORE)
www.jrl-ore.com



"Aulas" BCAM – UPV/EHU in Leioa and Donostia-San Sebastián



Joint Research Lab on Artificial Intelligence (JRL-AI)
www.jrlab.science



PET MSO-ED
Spanish Platform for Modelling, Simulation and Optimization Technologies in a Digital Environment
www.math-in.net/?q=es/content/pet-mso-ed

3. Thematic networks



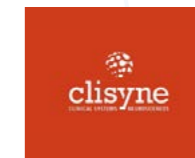
MATH-IN
Spanish Network of Mathematics and Industry
www.math-in.net



BIOSTATNET
National Network of Biostatistics
www.biostatnet.com



RGAS
Algebraic Geometry and Theory of Singularities
www.blogs.mat.ucm.es/rgas/objectives/



CLISYNE
Clinical Systems Neuroscience
www.clisyne.org

4. Associations & consortiums



ECMI
European Consortium for Mathematics in Industry
www.ecmiindmath.org



BAIC
Basque Artificial Intelligence Center
www.baic.eus/es



BDIH
Basque Digital Innovation Hub
www.basqueindustry.spri.eus/es/basque-digital-innovation-hub/



INNOLAB
Bilbao
www.ilb.eus/en



EARMA
European Association of Research Managers and Administrators
www.earma.org



BCSC
Basque CyberSecurity Centre
www.basquecybersecurity.eus



BAT
B Accelerator Tower
www.bacceleratortower.com



EOSC
European Open Science Cloud
www.eosc-portal.eu

Societies

We are institutional members of the following societies:



EMS
European Mathematical Society
www.euromathsoc.org



SEMA
Sociedad Española de Matemática Aplicada
www.sema.org.es/es



RSME
Real Sociedad Matemática Española – RSME
www.rsme.es

Agreements

1. BASQUE COUNTRY

- Achucarro
- AQUADAT Efficient Innovation SL
- Athletic Club
- Ayuntamiento de Bilbao
- BEAZ
- Bilbao Ekintza EPEL
- BioAraba
- CFAA-Centro de fabricacion avanzada aeronautica
- CIC bioGUNE
- DIPC (Donostia International Physics Center)
- EITB - Euskal Irrati Telebista
- Elhuyar
- Emergencias Osakidetza
- ETSI Bilbao
- Euskampus/BCAM/Universidad de Burdeos
- GHI Hornos Industriales
- Ikerbasque (IBM)
- Innovation Data Space Iberdrola
- Insertec
- Kronikgune
- Mondragon Unibertsitatea- Facultad de Empresariales
- MoU Global Smart Grid Innovation Hub (Iberdrola Distribución Eléctrica)
- Nautilus Floating Solutions SL
- Osakidetza
- OSI Barrualde Galdakao + BIOEF
- Polymat
- PwC - PricewaterhouseCoopers
- REM Master
- Saitec Offshore S.L.
- Tecnalía - Plan Complementario de Materiales Avanzados
- UPV - Computational Engineering Master
- UPV - Modelisation and Mathematical Research Master
- UPV/EHU
- UPV/EHU Tecnalía
- UPV/EHU aula bcam en Donosti
- UPV/EHU aula bcam en Leioa
- UPV/EHU EUSKAMPUS
- Ventijet Health Technology S.L.

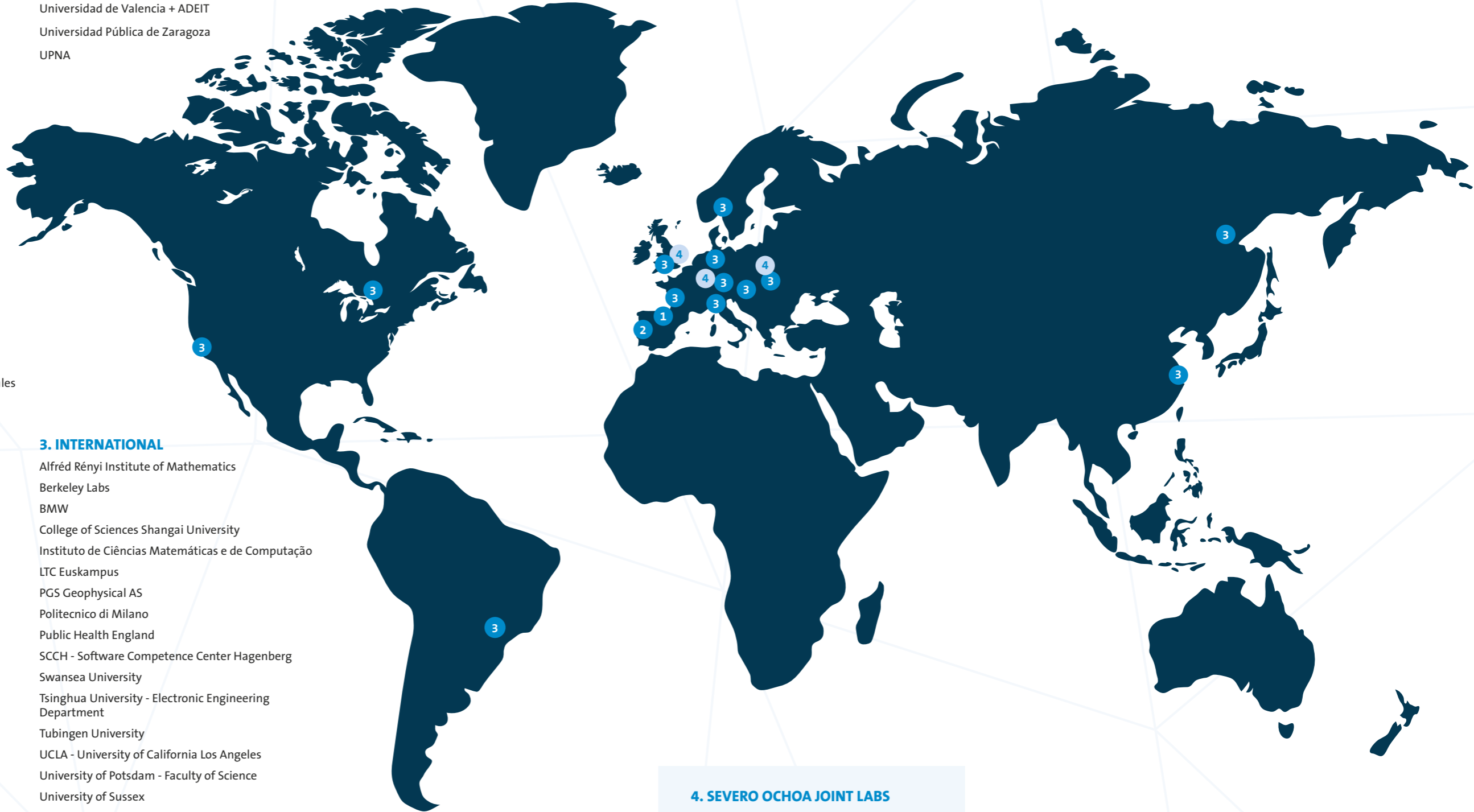
- Sedical
- Universidad da Coruña
- Universidad de Salamanca- USAL
- Universidad de Valencia + ADEIT
- Universidad Pública de Zaragoza
- UPNA

3. INTERNATIONAL

- Alfréd Rényi Institute of Mathematics
- Berkeley Labs
- BMW
- College of Sciences Shanghai University
- Instituto de Ciências Matemáticas e de Computação
- LTC Euskampus
- PGS Geophysical AS
- Politecnico di Milano
- Public Health England
- SCCH - Software Competence Center Hagenberg
- Swansea University
- Tsinghua University - Electronic Engineering Department
- Tubingen University
- UCLA - University of California Los Angeles
- University of Potsdam - Faculty of Science
- University of Sussex
- University of Trieste
- UPV/EHU EUSKAMPUS
- Wenzhou Institute (Univ. of Chinese Academy of Sciences)
- Wilfrid Laurier University

4. SEVERO OCHOA JOINT LABS

- ETH Zurich
- Oxford University
- Rényi Insitute
- University of Sussex





*Basque Center for
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2023



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