

# 2018

# ANNUAL REPORT



Continuous problem:

$$(*) \begin{cases} \dot{y}(t) = L_{11} y_t + L_{12} z_t, & t \geq 0 \\ \dot{z}(t) = L_{21} y_t + L_{22} z_t, & t \geq 0 \\ (y_0, z_0) = (\phi, \psi) \in Y \times Z \end{cases}$$

$$Y := L^*([z, 0], \dots, [z, 0])$$

$$Z := ([z, 0], \mathbb{R})$$

Discrete problem:

$$M \in \mathbb{R}^{M \times M}, M > 0$$

$$\theta = (\theta_0, \theta_1, \dots, \theta_M)$$

$$\theta_{M+1} = \theta_M = -z$$

$$Y_n := \mathbb{R}^{M \times (M+1)} \simeq \mathbb{R}^n$$

$$Z_n := \mathbb{R}^{M+1}$$

$$\Phi = (\phi_0, \dots, \phi_M) \in Y_n$$

$$\Psi = (\psi_0, \dots, \psi_M) \in Z_n$$

$$(\Phi, \Psi) \in Y_n \times Z_n$$

$$P_n, Q_n : [-z, 0] \rightarrow \mathbb{R}$$

$$(P_n, Q_n) \in Y \times Z$$

$$P_n(\theta_0) = \bar{L}_{11} P_n + \bar{L}_{12} Q_n$$

$$P_n(\theta_i) = \Phi_i \quad i = 1, \dots, M$$

$$Q_n(\theta_i) = \Psi_i \quad i = 0, 1, \dots, M$$

$$\mathcal{A}_n : Y_n \times Z_n \rightarrow Y_n \times Z_n$$

$$\mathcal{A}_n(\Phi, \Psi) = \begin{cases} \beta_i = \Phi_i(\theta_i) & i = 1, \dots, M \\ \eta_i = \Psi_i(\theta_i) & i = 0, 1, \dots, M \end{cases}$$

$$\mathcal{A}_n = \begin{pmatrix} \text{---} \\ \text{---} \\ \text{---} \\ \text{---} \end{pmatrix}$$

$$\mathcal{X}(\phi, \psi) = (\phi, \psi)$$

$$D(\mathcal{X}) = \{(\phi, \psi) \in Y \times Z : \begin{cases} \phi(0) = L_{11} \phi + L_{12} \psi \\ \phi'(0) = L_{21} \phi + L_{22} \psi \\ (u_0, z_0) = (u(t), v(t)) \end{cases}\}$$

$$(*) \simeq \left\{ \frac{d}{dt} (u(t), v(t)) = \mathcal{X}(u(t), v(t)), (u(0), v(0)) = (\phi, \psi) \in D(\mathcal{X}) \right\}$$

$$\mathcal{A}_n = \mathcal{D}$$

→ The eigenvalues

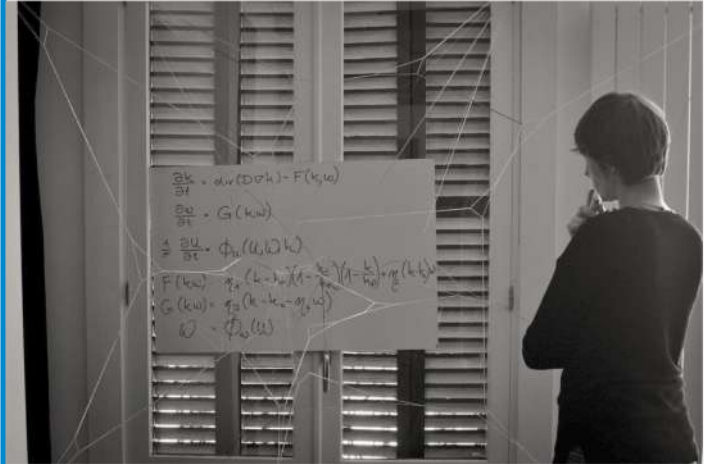
$$\lambda \in \sigma(\mathcal{A}_n)$$

$$\lambda_n \in \sigma(\mathcal{A}_n)$$

$$\lambda_n \rightarrow \lambda$$

“If people do not believe that mathematics is simple, it is only because they do not realize how complicated life is”

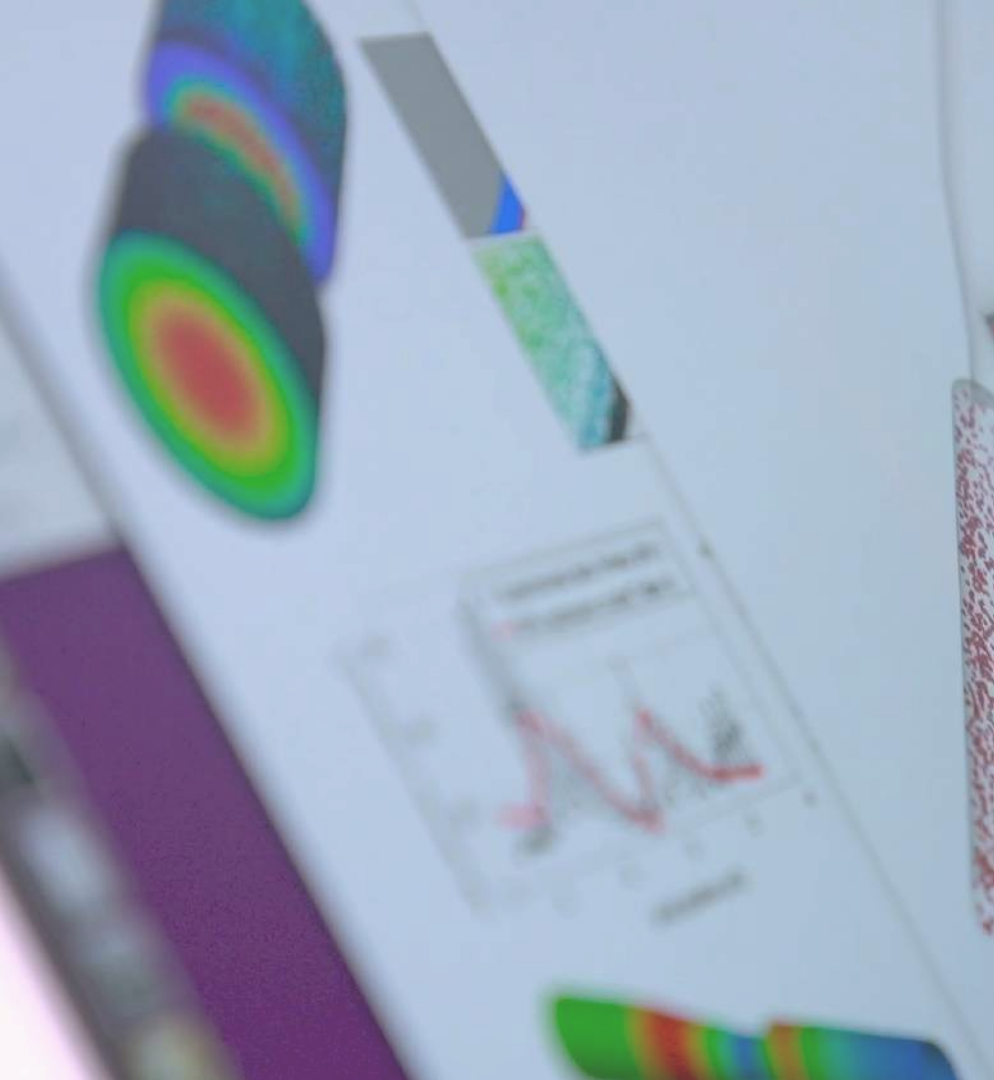
—von Neumann, 1947



# TABLE OF CONTENTS

Research Areas	01
People	02
Scientific Output	03
Programmes	04
Collaborators	05
Funding	06
Dissemination	07





01

## RESEARCH AREAS

- **Objective:** To develop new mathematical methods, robust numerical schemes and software to solve complex and large-scale challenging real-life problems on massively parallel computers.
- **Description:** We analyse modern numerical methods such as advanced Finite Element (AFE) and Finite Volume (FV) techniques applied to stationary and time-dependent problems. In addition, we develop new meshless multi-scale methods such as Smoothed Particle Hydrodynamics (SPH) or Dissipative Particle Dynamics (DPD) applied to complex fluids and mesoscopic flow problems.
- **Applications:** Characterisation of the Earth's subsurface composition for CO<sub>2</sub>- sequestration and oil or gas extraction; dynamics of complex particulate fluids, microfluidics, rheology; CFD applied to complex flows that rise in a number of engineering sectors including environmental, chemical/manufacturing, polymer/ food processing and biomedicine.



## Mathematical modelling with multidisciplinary applications

- **Objective:** Development of novel theoretical and computational tools for efficient and detailed simulation of multi- scale complex systems describing real life problems in biology, medicine, public health and society.
- **Description:** Improved algorithms, efficient sampling techniques, advanced models combined with observational data ensure a full exploitation of the capabilities of modern HPC in tackling the mathematical challenge of strong coupling across scales, adaptive and emergent dynamics. Pushing the boundaries of mathematics and interdisciplinary knowledge helps to reveal hidden structures of the complex systems.
- **Applications:** Patient-specific simulation (cardiovascular, brain, cancer), neurodegenerative diseases, drug design, self-assembly in bio-chemical processes, energy materials modelling and uncertainty quantification. Targeted at biologists, clinicians and industries.



- **Objective:** At the interface between Mathematics and Physics is the so-called Mathematical Physics that at BCAM is represented by the research lines in Quantum Mechanics, Statistical Physics and Singularity Theory & Algebraic Geometry.
- **Description:** We study several questions of classical physics that although long known, are still not understood from the mathematical perspective, microscopic origin of macroscopic laws (like in electricity) and natural phenomena of front motion embedded into random environments. More theoretically, we study the geometry of Singularities appearing in Algebraic Geometry.
- **Applications:** Our methods could apply to, future applications of quantum technologies or forecast of wildland fire propagation to preserve natural heritage, cryptography and string theory.



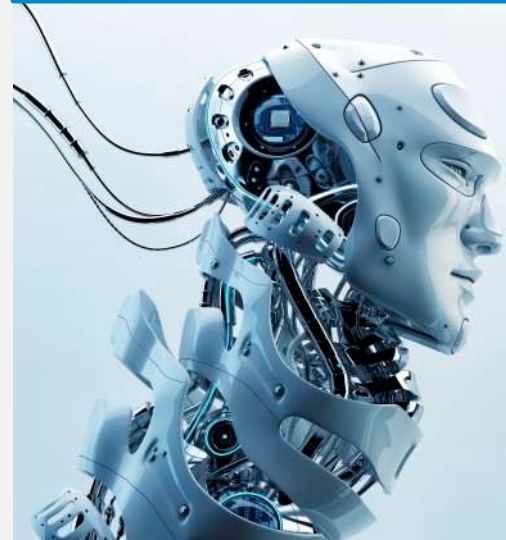
04  
**APDE**  
Analysis of  
Partial  
Differential  
Equations

- **Objective:** We explore and exploit the deep connections between Partial Differential Equations, Harmonic Analysis, and Applied Mathematics so as to describe the most diverse phenomena.
- **Description:** The attempt to efficiently describe real-life phenomena leads to mathematical models, often expressed in terms of PDEs, capturing the essential features of the phenomena. Solving these equations implies the use and development of sophisticated techniques of analysis together with the realisation of numerical simulations to eventually determine the validity of the models.
- **Applications:** The understanding of the fundamental principles that control relevant phenomena in physics and biology could eventually become of use for scientists working on those fields. We also expect to apply the efficient algorithms developed by our numerical simulations in real life problems.





- **Objective:** To develop new statistical, machine learning and optimisation methods that can extract knowledge from the large amount of data generated nowadays.
- **Description:** In the applied statistics field, the main topics of our research are semi-parametric regression, multidimensional smoothing, (Bayesian) hierarchical models, computational statistics... Regarding Machine learning, we work on supervised and unsupervised classification of massive data, probabilistic graphical models, time series, Bayesian optimisation, etc. In optimisation we pursue the developments of efficient metaheuristics methods.
- **Applications:** Massive data and optimisation problems from financial to social media, marketing, medical domains (diagnosis and prognosis), genetics, environmental modelling, demography and biostatistics, logistics, scheduling and planning.



# PEOPLE

02



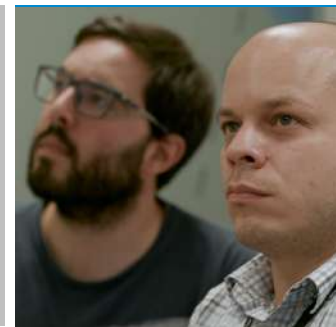
93  
people

+22 more  
than in  
2017



1  
Scientific  
Director

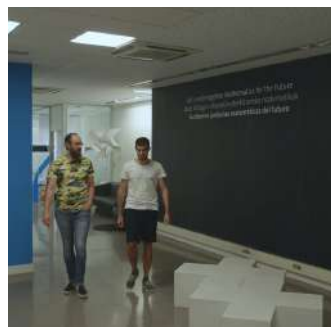
22  
Research line  
leaders and BCAM  
researchers



34  
Postdoctoral  
fellows

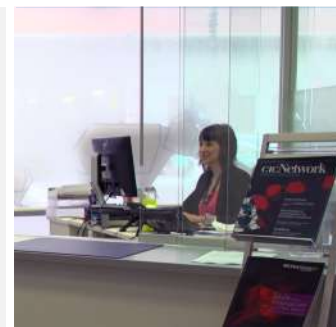


8  
Administration  
Staff Members  
and IT Technician



2  
KTU Research  
Technicians

22  
External Scientific  
Members



## HRS4R: HUMAN RESOURCES STRATEGY FOR RESEARCHERS

BCAM received the **HR Excellence in Research Award** in 2016. This recognition by the European Commission identifies the universities and institutions that generate and support the existence of a stimulating and favourable environment for research work by adapting their human resources policies to the 40 principles of the European Charter & Code for Researchers.

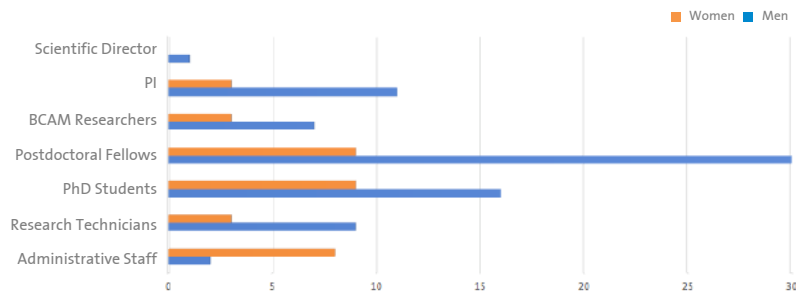
In May 2019 assessors from the European Commission concluded that the implementation of the Action Plan at BCAM was progressing appropriately and the center **successfully passed the first Internal Review** of the HR Excellence in Research Award.



### HIGHLIGHTS OF THE HRS4R ACTION PLAN:

- Yearly **Training and Development plan** (technical and non-technical)
- Implementation and monitoring of the **Gender Equality Plan**
- **New offices** to provide more space for researchers within the Bizkaia Science and Technology Park (Leioa)
- Organization of leisure and **team building activities**
- Creation of the **BCAM Management Committee** to evaluate the distribution of funding for BCAM programs and personnel per area and the performance evaluation of researchers.
- Elaboration of a **Work-Life Balance** document for employees
- Dissemination of the **Career Development Plan**

## DISTRIBUTION OF THE STAFF BY GENDER:



# GENDER EQUALITY PLAN

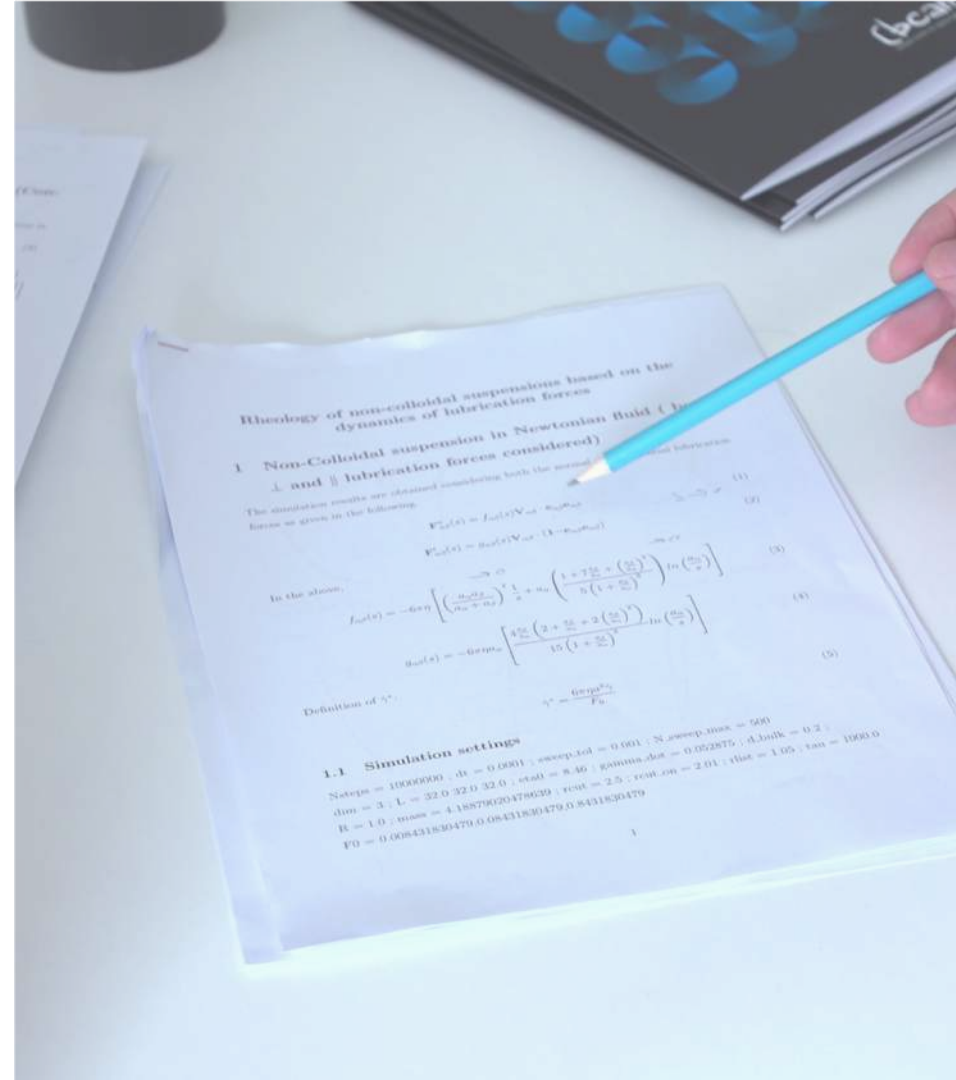
## HIGHLIGHTS OF THE GENDER EQUALITY PLAN:

- Constitution of the **Equality Commission**
- Annual **training in Gender Equality** for all staff members to promote employee awareness in this area.
- Partnership agreement with the **Women for Africa Foundation (FMxA)** to host an African woman researcher for 6 months.
- Twitter contest to name the Seminar Room at BCAM after a woman mathematician, which is now the **“Maryam Mirzakhani Seminar room”**
- Support in the creation of **R-ladies Bilbao**, a group promoting diversity in the R community via meetups, mentorship & global collaboration



# SCIENTIFIC OUTPUT

03

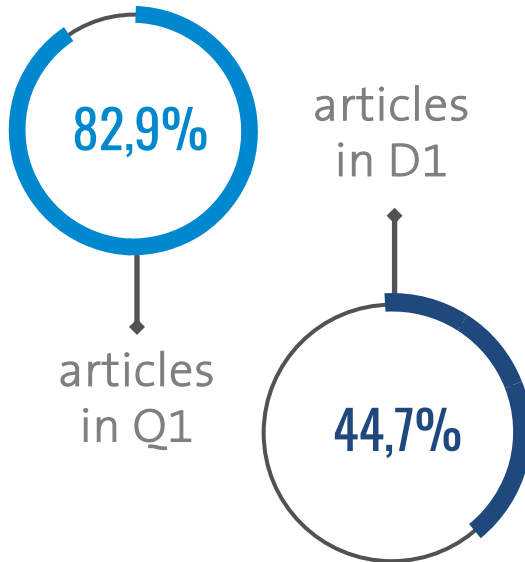


## SCIENTIFIC PUBLICATIONS



178

PUBLICATIONS  
INDEXED



BCAM H-INDEX

29



# 1<sup>st</sup> DECILE JOURNALS



- Advances in Mathematics
- Analysis and PDE
- Analytica Chimica Acta
- Archive for Rational Mechanics and Analysis
- Clinical Epidemiology
- Communications in Mathematical Physics
- Computer Methods in Applied Mechanics and Engineering
- Computers and Operations Research
- Discrete and Continuous Dynamical Systems- Series A Duke
- Mathematical Journal
- Environmental Modelling and Software
- ESAIM: Mathematical Modelling and Numerical Analysis
- European Journal of Epidemiology
- European Journal of Operational Research
- Fractional Calculus and Applied Analysis
- ICES Journal of Marine Science
- IMA Journal of Numerical Analysis
- International Journal for Numerical Methods in Engineering
- Journal of Algebraic Geometry
- Journal of Computational Physics
- Journal of Differential Equations
- Journal of Fluid Mechanics
- Journal of Functional Analysis
- Journal of Geometric Analysis
- Journal of Nonlinear Science
- Journal of Physical Chemistry C
- Journal of Spectral Theory
- Journal of the London Mathematical Society
- Journal of Royal Society Interface
- Journal of Topology
- Language Learning
- Marine Structures
- Neural Networks
- New Journal of Physics
- Nonlinear Analysis, Theory, Methods and Applications
- Nonlinearity
- Progress in Aerospace Sciences
- Revista Matemática Iberoamericana
- Science Advances
- SIAM Journal on Mathematical Analysis
- SIAM Journal on Numerical Analysis
- Spatial Statistics
- Transportation Research Part C: Emerging Technologies



# MASTER & PHD THESIS

33

ONGOING PHD  
STUDENTS IN 2019



+3

NEW PHD STUDENTS

THESIS DEFENDED  
IN 2018

13

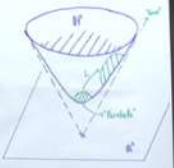


5

MASTER THESIS  
DEFENDED  
IN 2018

# TOPIC 3.2. NONEXISTENCE OF EXTREMIZERS ON THE HYPERBOLOID

**DEF.**  $H^1 = \{(x, y, z) \in \mathbb{R}^3 : x^2 + y^2 - z^2 = 1\}$   
 (noncompact submanifold of Lorentz transformations in  $\mathbb{R}^{3,1}$ )  
**EXTREMIZATION PROBLEM:**  
 $Tf(x, y, z) = \int_{-\infty}^{\infty} e^{-|t|} e^{i(xt + yt - zt^2)} dt = \int_{-\infty}^{\infty} e^{-|t|} e^{i(x + y - zt^2)t} dt$   
 $Tf(x, y, z) \in C_0 \cap L^1(\mathbb{R}^3) \Rightarrow \int_{\mathbb{R}^3} |Tf(x, y, z)| dx dy dz < \infty$



**THEOREM:** The best constants for  $(x, y, z) = (1, 0, 0), (0, 1, 0), (0, 0, 1)$  are  
 $M_{1,1} = 2^{1/2} \pi^{1/2} ; M_{1,0} = (2\pi)^{1/2} ; M_{0,1} = (2\pi)^{1/2}$   
 Extremizers do not exist in each of the classes.

**EQUIVARIANT SUBALGEBRA**  
 $\{f(x, y, z) = \int_{-\infty}^{\infty} e^{-|t|} e^{i(xt + yt - zt^2)} dt\}$

**REDUCTION OF VARIABLES:**  
 $\int_{\mathbb{R}^3} |Tf(x, y, z)| dx dy dz = \int_{\mathbb{R}^3} |Tf(x, y, z)| dx dy dz$

## FOSCHIS ARGUMENT

$$\langle u, v \rangle = \int_{\mathbb{R}^3} u(x, y, z) \overline{v(x, y, z)} dx dy dz$$

$$= \int_{\mathbb{R}^3} \frac{u(x, y, z) \overline{v(x, y, z)}}{\sqrt{x^2 + y^2 - z^2}} \sqrt{x^2 + y^2 - z^2} dx dy dz$$

$$= \int_{\mathbb{R}^3} \frac{u(x, y, z) \overline{v(x, y, z)}}{\sqrt{x^2 + y^2 - z^2}} dx dy dz$$

Cauchy-Schwarz

$$\left| \int_{\mathbb{R}^3} \frac{u(x, y, z) \overline{v(x, y, z)}}{\sqrt{x^2 + y^2 - z^2}} dx dy dz \right| \leq \left( \int_{\mathbb{R}^3} \frac{|u(x, y, z)|^2}{x^2 + y^2 - z^2} dx dy dz \right)^{1/2} \left( \int_{\mathbb{R}^3} |v(x, y, z)|^2 dx dy dz \right)^{1/2}$$

Equality holds iff  $u(x, y, z) = \lambda \sqrt{x^2 + y^2 - z^2} v(x, y, z)$

**CASES OF EQUALITY:**  
 (a)  $f(x, y, z) = \int_{-\infty}^{\infty} e^{-|t|} e^{i(xt + yt - zt^2)} dt$



**EXPLICIT FORMULAS**  
 $\langle f, f \rangle = \int_{\mathbb{R}^3} |f(x, y, z)|^2 dx dy dz = \int_{\mathbb{R}^3} \frac{|f(x, y, z)|^2}{x^2 + y^2 - z^2} dx dy dz$   
 $\langle f, f \rangle = \int_{\mathbb{R}^3} \frac{|f(x, y, z)|^2}{x^2 + y^2 - z^2} dx dy dz$   
 $\langle f, f \rangle = \int_{\mathbb{R}^3} \frac{|f(x, y, z)|^2}{x^2 + y^2 - z^2} dx dy dz$

**CONCLUSION:**  
 $p = 1$  - Character of extremizers  
 $p = 0$  - Character of extremizers  
 $M(1, 1) = \int_{\mathbb{R}^3} \frac{|f(x, y, z)|^2}{x^2 + y^2 - z^2} dx dy dz$

## PARTICIPANTS IN OUR PROGRAMMES

23 Visiting fellows

31 Interns

205 Visitors



# COLLABORATORS

05





**ikerbasque**  
Basque Foundation for Science

**innobasque**  
berrikuntzaren euskal agentzia / agencia vasca de la innovación

**Bizkaia**  
foru aldundia / diputación foral

Universidad del País Vasco / Euskal Herriko Unibertsitatea

**euskampus**  
FUNDAZIOA

**Deusto**  
Universidad de Deusto

**Mondragon Unibertsitatea**

**bcbl**  
BASQUE CENTER ON COGNITION, BRAIN AND LANGUAGE

**bc<sup>3</sup>**  
BASQUE CENTRE FOR CLIMATE CHANGE / Klima Aldaketa Ikergai

**POLYMAT**  
Basque Center for Macromolecular Design and Engineering

**Achucarro**  
BASQUE CENTER FOR NEUROSCIENCE

**BASQUE CYBERSECURITY CENTRE**

**CIC energigUNE**  
energy cooperative research centre

**CIC bioGUNE**  
MEMBER OF BASQUE RESEARCH & TECHNOLOGY ALLIANCE

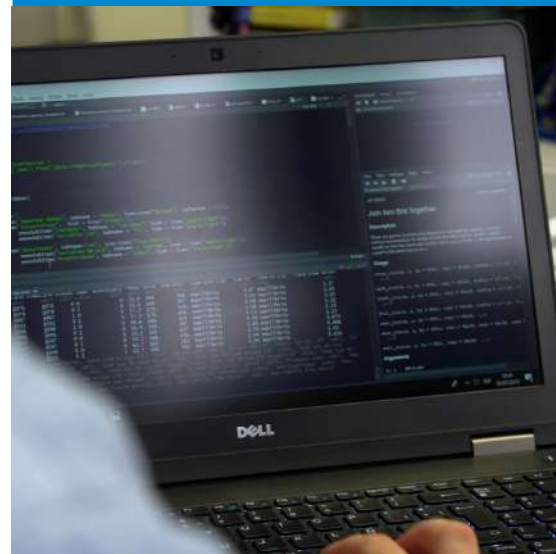
**biocruces bizkaia**  
osasun ikerketa institutua / Instituto de Investigación Sanitaria

**tecnalia** Inspiring Business

**IK4** Research Alliance

**inno lab bilbao**

COLLABORATORS IN THE FRAMEWORK OF THE BASQUE SCIENCE, TECHNOLOGY & INNOVATION NETWORK





## INDUSTRIAL COLLABORATORS



## NEW INTERNATIONAL AGREEMENTS

INRIA – INVENTEURS DU  
MONDE NUMÉRIQUE  
UNIVERSITÉ DE BORDEAUX  
UNIVERSITÉ DE TOULOUSE  
UNIVERSITY OF BRISTOL  
KTH – ROYAL INSTITUTE OF  
TECHNOLOGY  
UNIVERSITY OF POSTDAM  
UNIVERSITY OF ZAGREB





06

FUNDING



# Let's write together Mathematics for the Future

## Idatz ditzagun elkarrekin etorkizuneko matematikak

### Escribamos juntos las matemáticas del futuro

$$\| \nabla \varphi \|$$

$$= \int_S \varphi(\bar{x}, t) \delta(x - \bar{x}) d\bar{x}$$

$$= \int_S \varphi(\bar{x}, t) \delta(x - X^\omega(t, \bar{x})) d\bar{x}$$

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

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

PARTICIPATING  
INSTITUTIONS





PUBLIC & PRIVATE  
FUNDING

DISSEMINATION

07



# GENERAL DISSEMINATION ACTIVITIES



## PROMOTION OF SCIENTIFIC VOCATIONS

Aupatuz, Talentia, First Lego  
League Euskadi...



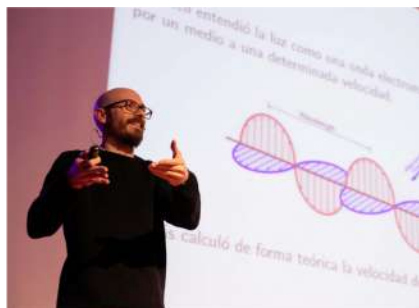
## PUBLIC DISSEMINATION

Bidebarrieta talks on  
Mathematics in everyday life,  
Bilbao Art District,  
Matemozinoa, Pint of Science...



## PRESS & OTHER MEDIA

TV, Radio...



## SOCIAL NETWORKS

Follow BCAM on Twitter  
(@BCAMBilbao), LinkedIn and  
Youtube



NEW  
INSTITUTIONAL  
VIDEO



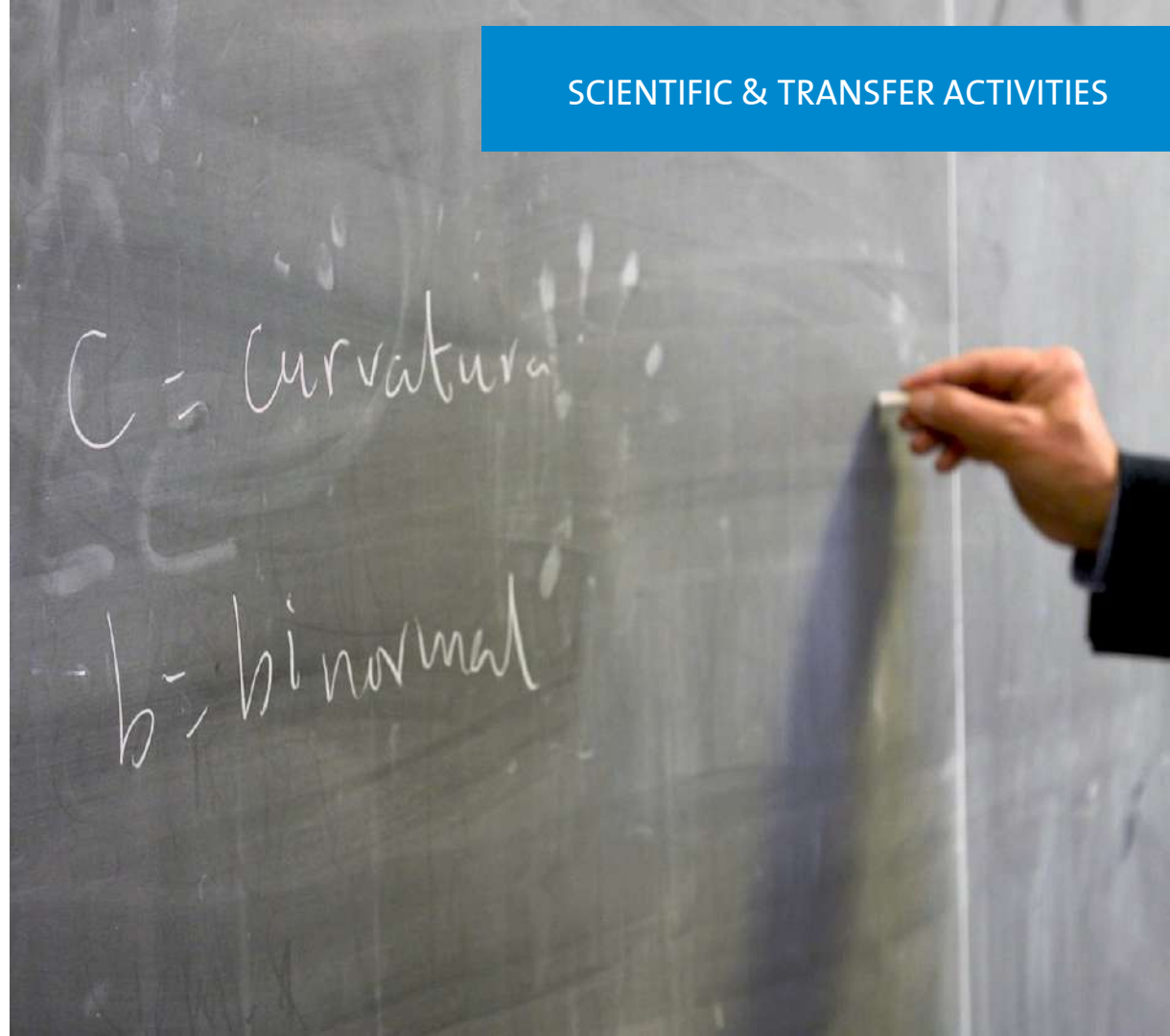
What is the  
Basque Center  
for Applied  
Mathematics?

55 seminars

8 workshops

13 courses

1 summer school



## SCIENTIFIC & TRANSFER ACTIVITIES



BCAM played an active role in the last edition of the International Congress on Industrial and Applied Mathematics that took place in Valencia from 15-19 July:

- The center had an **academic exhibitor**
- A video about the center was broadcasted on ICIAMTV
- 18 BCAM researchers participated as **speakers** at ICIAM minisymposia





basque center for applied mathematics

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