

# 2019

# 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:

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

$$\theta_i = \theta_0, \theta_1, \dots, \theta_M$$

$$\theta_{i+1} > \theta_i > \theta_{i-1} > \dots > \theta_0 = -z$$

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

$$\mathbb{R}^{M \times M} \simeq \mathbb{R}^{M \times M}$$

$$\Phi = (\phi_1, \dots, \phi_n) \in Y_n$$

$$\Psi = (\psi_1, \dots, \psi_n) \in Z_n$$

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

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

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

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

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

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

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

$$\mathcal{A}_n(\Phi, \Psi) = \begin{cases} \beta_i = \dots(\theta_i) & i = 1, \dots, M \\ \eta_i = \dots(\theta_i) & i = 1, \dots, M \\ \eta_i = Q_n'(\theta_i) & i = 2, \dots, M \end{cases}$$

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

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

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

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

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

→ The eigenvalues

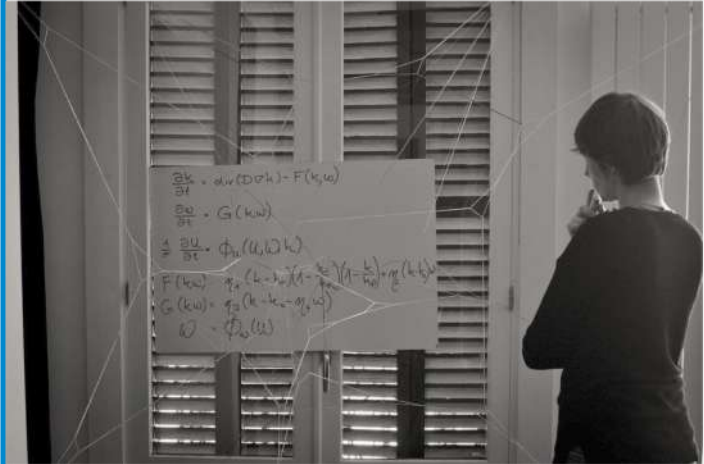
$$\lambda \in \sigma(\mathcal{A}_n)$$

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

$$\lambda_n \rightarrow \lambda$$

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

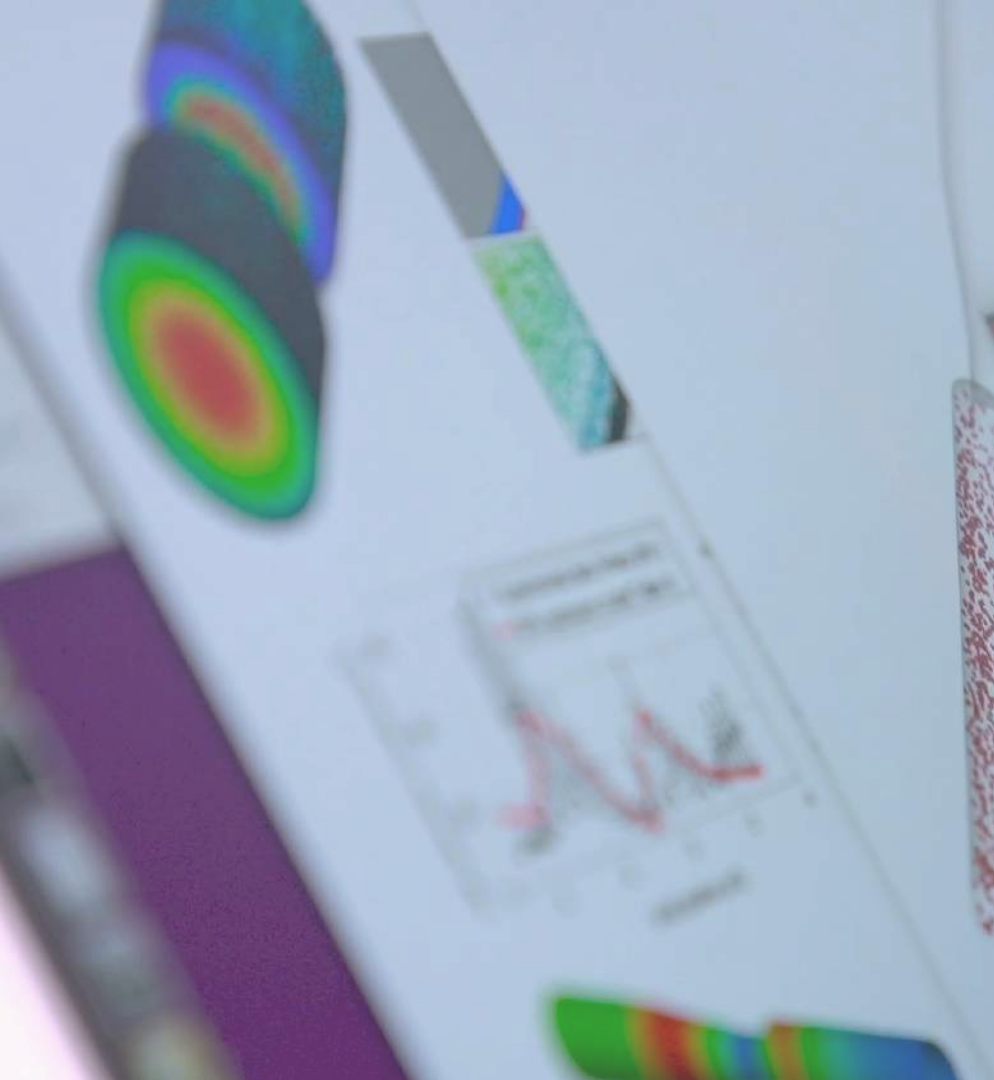
—von Neumann, 1947



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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.





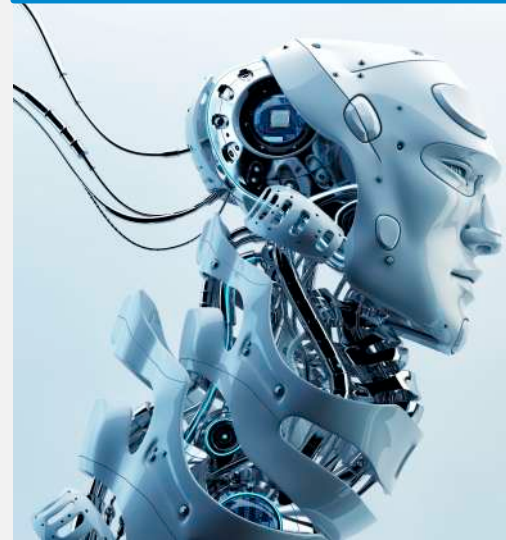
04  
**APDE**  
Analysis of  
Partial  
Differential  
Equations

- **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



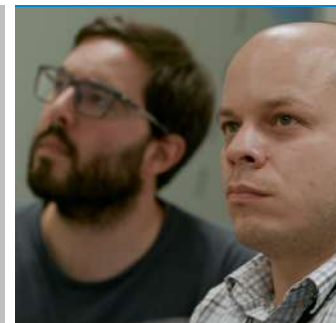
108  
people

+22 more  
than in  
2018



1  
Scientific  
Director

23  
Research line  
leaders and BCAM  
researchers



39  
Postdoctoral  
fellows

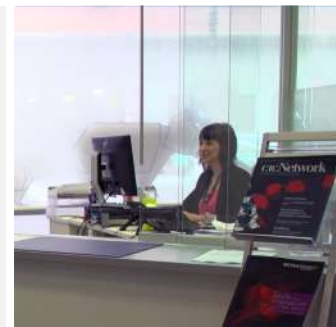


9  
Administration  
Staff Members



10  
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.

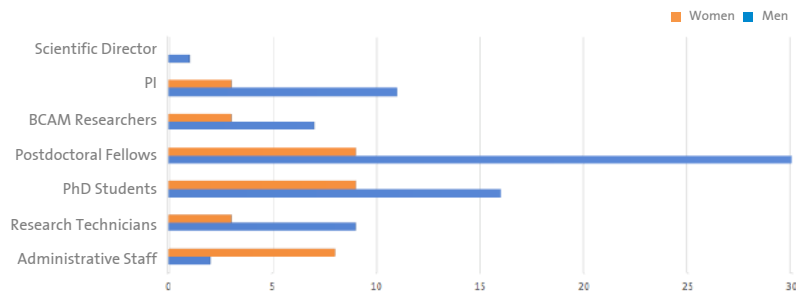
In May 2019 assessors from the European Commission concluded that the implementation of the Action Plan at BCAM was progressing appropriately and the center **successfully passed the first Internal Review** of the HR Excellence in Research Award.



### 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**

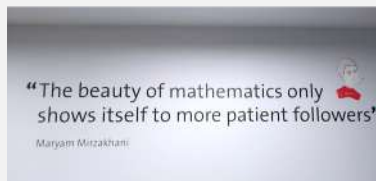
## DISTRIBUTION OF THE STAFF BY GENDER:



# GENDER EQUALITY PLAN

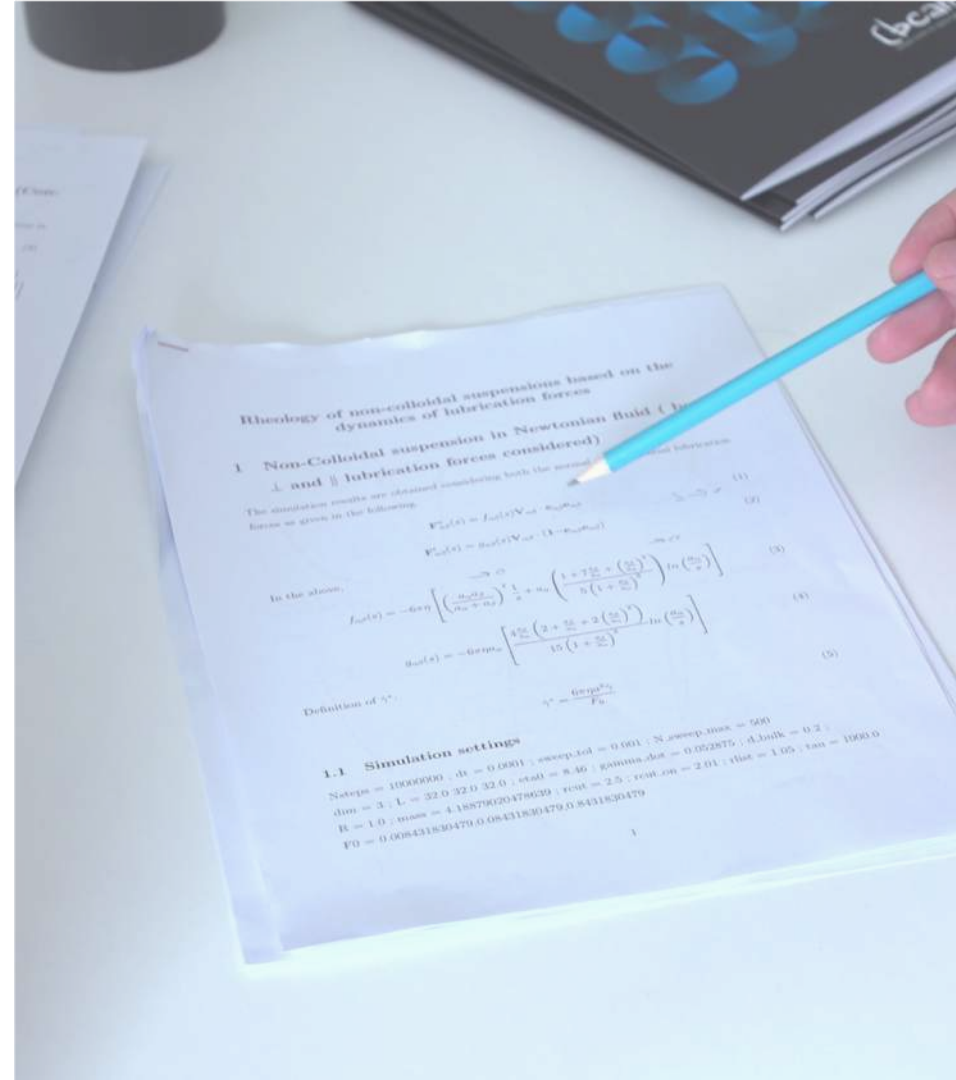
## HIGHLIGHTS OF THE GENDER EQUALITY PLAN:

- 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

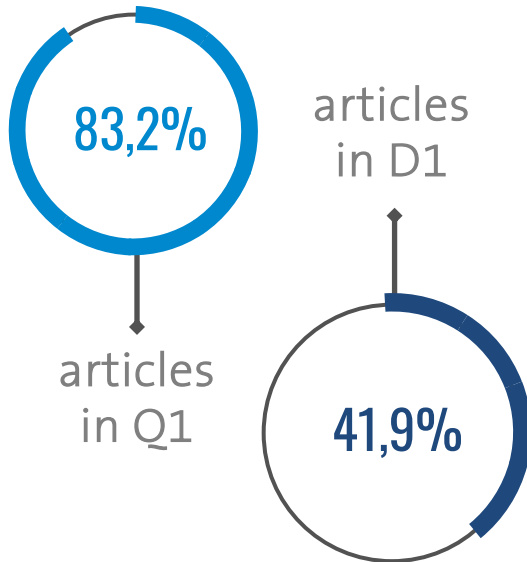


# SCIENTIFIC PUBLICATIONS



191

PUBLICATIONS  
INDEXED



BCAM H-INDEX

33





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



- ACS Applied Materials and Interfaces
- ACS Macro Letters
- ACS Synthetic Biology
- Acta Materialia
- Annali di Matematica Pura ed Applicata
- Archive for Rational Mechanics and Analysis
- Astrophysical Journal
- Bernoulli
- Calculus of Variations and Partial Differential Equations
- Communications in Partial Differential Equations
- Computer Methods in Applied Mechanics and Engineering
- Environmental Modelling and Software
- Geoscientific Model Development
- Information Fusion
- Information Sciences
- International Journal for Numerical Methods in Engineering
- International Journal of COPD
- International Mathematics Research Notices
- Journal des Mathematiques Pures et Appliquees
- Journal of Computational Physics
- Journal of Differential Equations
- Journal of Fluid Mechanics
- Journal of Functional Analysis
- Journal of Geometric Analysis
- Journal of Hydrology
- Journal of Medical Internet Research
- Journal of Proteome Research
- Macromolecules
- Mathematische Annalen
- Metabolic Engineering
- Nature Communications
- Nature Reviews Microbiology
- New Journal of Physics Nonlinearity
- Physical Review B
- Proceedings of the IEEE
- R Journal
- Renewable and Sustainable Energy Reviews
- Scientific Reports
- Selecta Mathematica, New Series
- SIAM Journal on Mathematical Analysis
- SIAM Journal on Numerical Analysis
- Sociological Methods and Research
- Statistics and Computing
- Transactions of the American Mathematical Society
- Transportation Research Part C: Emerging Technologies

# MASTER & PHD THESIS

27

ONGOING PHD  
STUDENTS IN 2019



THESIS DEFENDED  
IN 2019

13



5

MASTER THESIS  
DEFENDED  
IN 2019

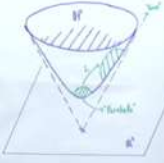
+11

NEW PHD STUDENTS

# TOPIC 3.2. NONEXISTENCE OF EXTREMIZERS ON THE HYPERBOLOID

after Steed Quispel

**DEF.**  $H^1 = \{(t, \frac{1}{\sqrt{1-t^2}}) \in \mathbb{R}^2 : |t| < 1\}$



**EXTREMALS:** Noncompact subgroup of Lorentz transformations  $\in \mathbb{R}^{2,1}$

**EXTREMAL PROBLEM:**  $Tf(x, s) = \int_{x_0}^{x_1} e^{-\lambda s} e^{s \sqrt{1-t^2}} dt = \int_{x_0}^{x_1} e^{-\lambda s} \frac{dt}{\sqrt{1-t^2}} = \ln \frac{1+t}{1-t} = 2 \operatorname{arctanh} t$

$\{Tf\}_{(x_0, x_1)} \in C_{\lambda, s} \iff \{f\}_{(x_0, x_1)} \in \mathcal{H}_{\lambda, s} = \{t \in \mathbb{R}^1 : |t| < 1\}$

**THEOREM:** The best constants for  $(s, p) = (1, 4), (2, 6), (3, 8)$  are  $H_{1,4} = 2^{1/4}$ ;  $H_{2,6} = (3/2)^{1/2}$ ;  $H_{3,8} = (2\sqrt{2})^{1/2}$ . Extremals do not exist in each of the cases.

**EQUIVALENT FORMULATION:**  $\|f\|_{p, \lambda} = \int_{x_0}^{x_1} |f(t)|^p e^{-\lambda s} dt = \|g\|_{p, \lambda}$

**PROPERTIES OF MEASURES:**  $\int_{x_0}^{x_1} |f| dx = \int_{x_0}^{x_1} |g| dx$

## FOSCHIS ARGUMENT $(p \in \mathbb{R}^+)$

$\langle u, v \rangle = \int_{x_0}^{x_1} u(x) v(x) dx = \int_{x_0}^{x_1} u(x) v(x) dx$

**Cauchy-Schwarz:**  $\left| \int_{x_0}^{x_1} u(x) v(x) dx \right| \leq \left( \int_{x_0}^{x_1} |u(x)|^2 dx \right)^{1/2} \left( \int_{x_0}^{x_1} |v(x)|^2 dx \right)^{1/2}$

**ORDERS OF EQUALITY:**  $f(x) = \sqrt{1-t^2}$



**EXPLICIT FORMULAS:**  $\langle u, v \rangle = \int_{x_0}^{x_1} u(x) v(x) dx = \int_{x_0}^{x_1} u(x) v(x) dx$

**CONCLUSION:**  $H^1$  is a cone of extremals

## PARTICIPANTS IN OUR PROGRAMMES

19 Visiting fellows

26 Interns

174 Visitors



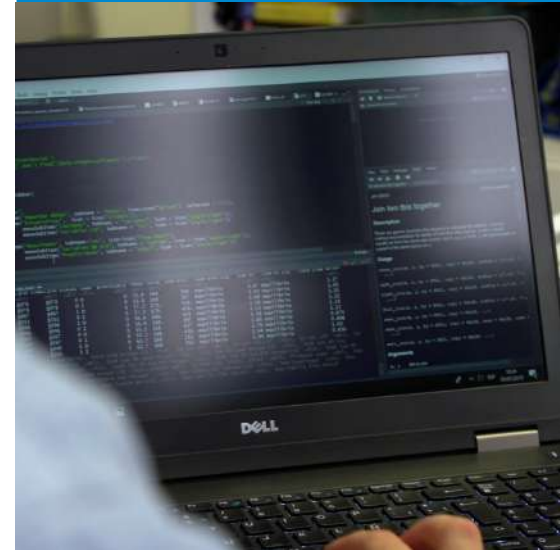
# COLLABORATORS

05





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







## INDUSTRIAL COLLABORATORS





## NEW INTERNATIONAL AGREEMENTS

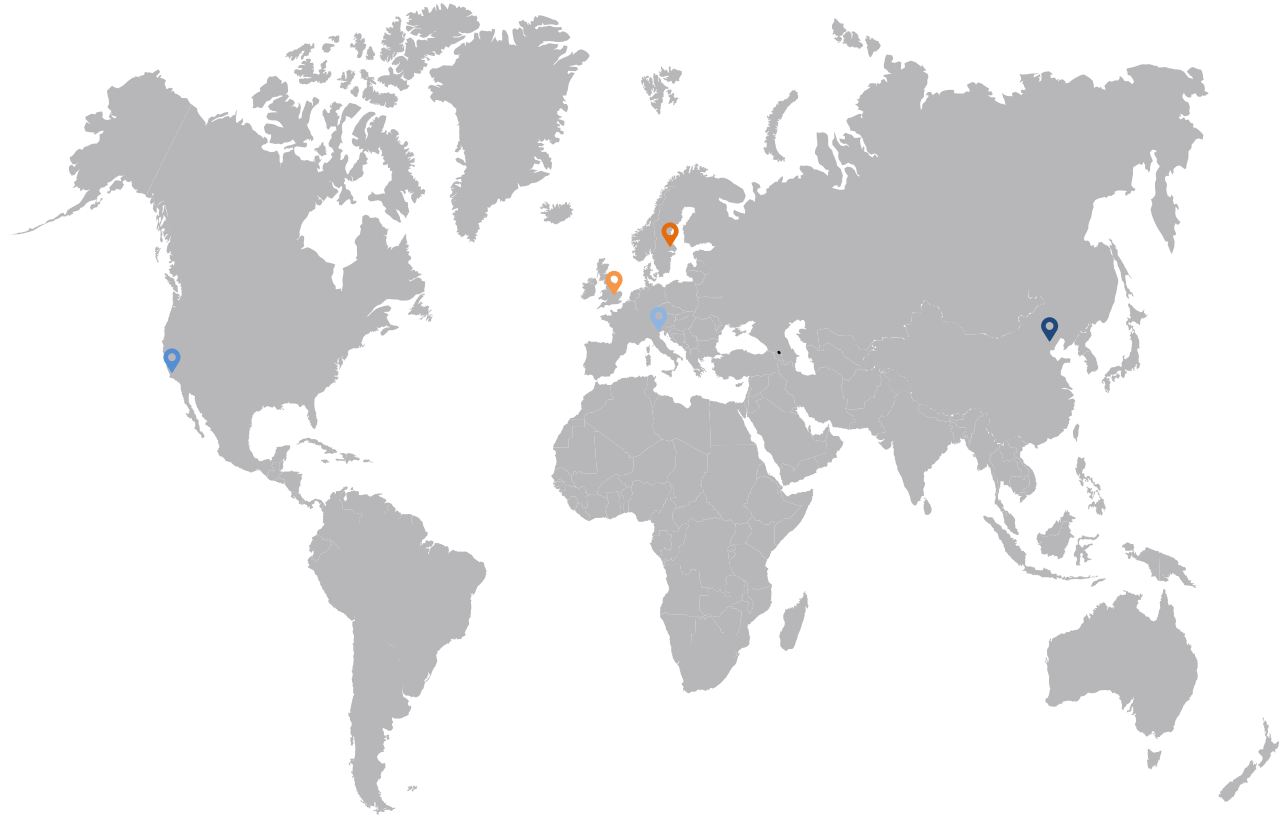
ISAAC NEWTON INSTITUTE  
FOR MATHEMATICAL  
SCIENCES

ICARUS DIGITAL MATH

ILLY CAFFE

THE UNIVERSITY OF  
CALIFORNIA - UCLA

TSINGUA UNIVERSITY





06

FUNDING

# Let's write together Mathematics for the Future

## Idatz ditzagun elkarrekin etorkizuneko matematikak

### Escribamos juntos las matemáticas del futuro

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

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

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

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

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

PARTICIPATING  
INSTITUTIONS





PUBLIC & PRIVATE  
FUNDING

DISSEMINATION 07





# GENERAL DISSEMINATION ACTIVITIES



## PROMOTION OF SCIENTIFIC VOCATIONS

Aupatuz, Talentia, First Lego  
League Euskadi...



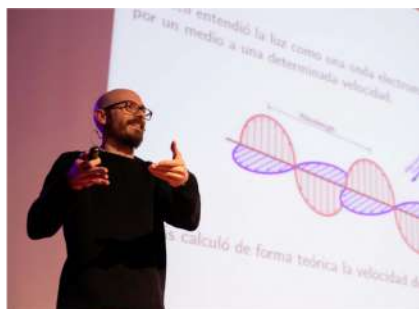
## PUBLIC DISSEMINATION

Bidebarrieta talks on  
Mathematics in everyday life,  
Pint of Science, BCAM-Naukas  
Pi Day, Bilbao Art District...



## PRESS & OTHER MEDIA

La mecánica del Caracol  
(Radio Euskadi), Zientzia  
Kaiera, Mapping  
Ignorance...



## SOCIAL NETWORKS

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



NEW  
INSTITUTIONAL  
VIDEO



What is the  
Basque Center  
for Applied  
Mathematics?



## 39 seminars

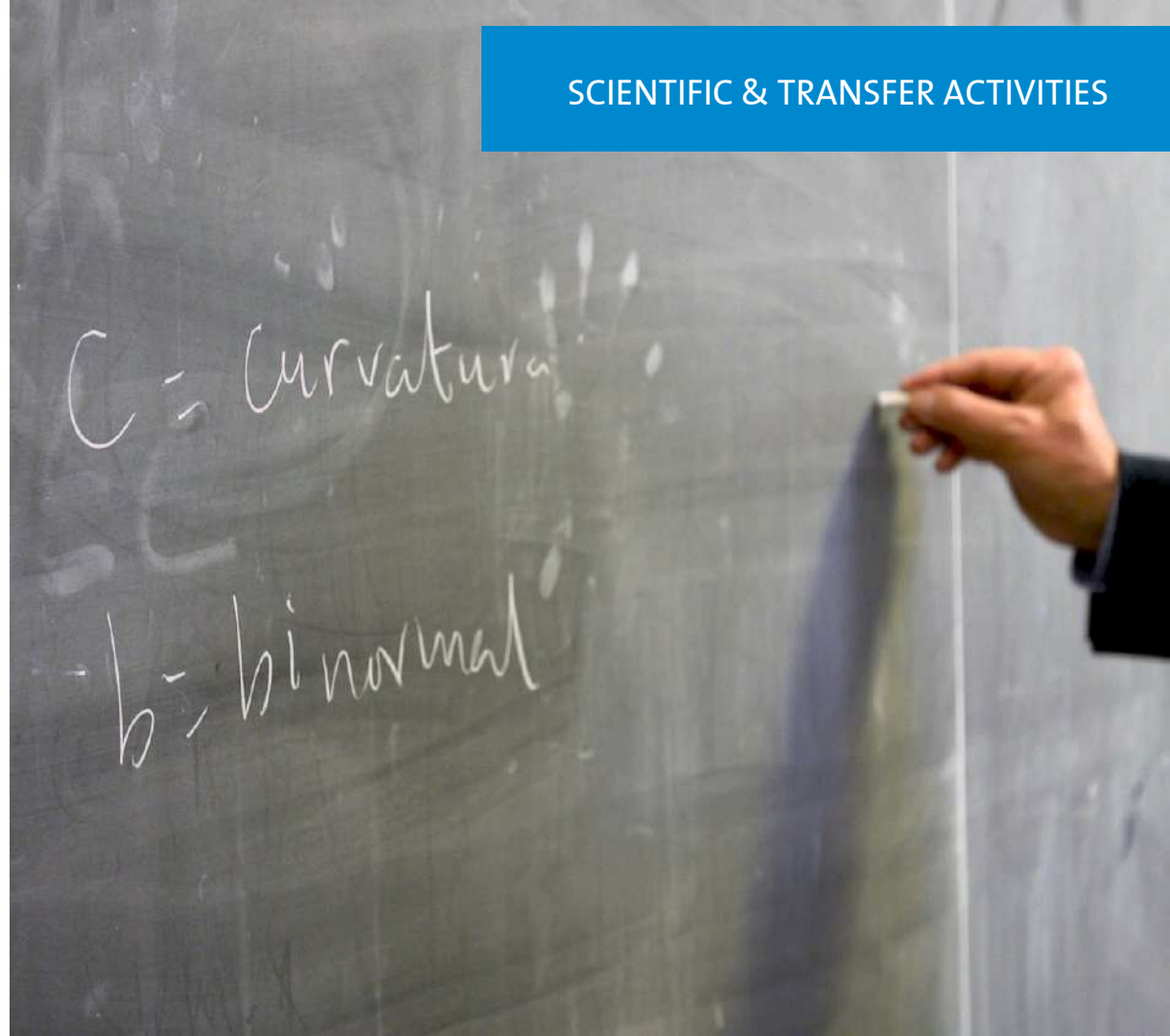
BCAM Scientific Seminars  
& Working groups

## 9 workshops

QBIO, BIDAS, FCPNLO...

## 17 courses

UPV/EHU Joint courses  
& BCAM Courses



## 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





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