IFISC: Institute for Cross-Disciplinary Physics and Complex Systems

Joint Research Institute of CSIC and UIB

Exploring emergent phenomena in the physical, technical, biological and social world.
IFISC: Institute for Cross-Disciplinary Physics and Complex Systems

Joint Research Institute of CSIC and UIB created in June 2007 building upon the former Cross-Disciplinary Physics Department of IMEDEA (1995)

**Mission:** Cross-Disciplinary and Strategic research in Complex Systems following the established scientific approach of physicists.

Cross-Disciplinary: Transfer of knowledge, concepts and methods to create bridges among traditional disciplines

Strategic: Focusing on advanced studies in emerging strategic fields with a strong potential impact, beyond the traditional physics of the XXth century. Avoid incremental research and the basic-applied polarization

**IFISC ASSESSMENT Strategic Plan CSIC 2010-13**

“IFISC is unique in the Spanish context and also has internationally a very strong standing. It challenges the world best centres and it is a major actor of emergence of complex science.”
Connecting Science, Understanding Complexity

Exploring emergent phenomena in the physical, technical, biological and social world
What are complex systems?

Complex Systems Society:

Complex systems are systems where the collective behavior of their parts entails emergence of properties that can hardly, if not at all, be inferred from properties of the parts. Examples of complex systems include ant-hills, ants themselves, human economies, climate, nervous systems, cells and living things, including human beings, as well as modern energy or telecommunication infrastructures.
CSIC staff: 3 Research Prof.
    1 Senior Researcher
    5 Tenured Scientists

UIB staff: 4 Full Prof.
    4 Prof.

Total permanent researchers: 17

Postdoctoral Research Associates: 16 (2 RyC, 1 Marie Curie, 2 Balear Government, 1 UIB lecturer, 10 project contracts)

International level: Spanish 6/17, EU 7/17, Rest of the world: 3/17

PhD contracts: 24 (6 Spanish FPI + FPU, 4 Balear Government, 9 Project contracts, Other: 5)

International level: Foreign 9/23 Mobility: UIB grad students 7/23

Long term visitors + associated: 13

Support personnel: 8

70 scientists 18 different nationalities
NEW CSIC staff:

Dr. Sandro Meloni, (June 2018)
PhD University Roma Tre, 2010
Ramon y Cajal fellow, BIFI, Zaragoza
Junior Scientific Award 2017 Complex Systems Society

Dr. Tobias Galla, (July 2019)
MSc Muenster, Germany, 2000
Phd Oxford 2004
Reader, School of Physics, Manchester
### VISITORS 2012-18

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<tr>
<th>Region</th>
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<th>Long Visits</th>
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### Personnel IFISC 2013-2018

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<th>Year</th>
<th>Permanent Staff</th>
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<th>PhD Students</th>
<th>Postdoctoral fellows</th>
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<td>Support personnel</td>
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<td><strong>Total</strong></td>
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10 YEARS CONNECTING SCIENCE, UNDERSTANDING COMPLEXITY

Internal synergies:
Network of joint publications 2007-17 among IFISC senior scientists

Talent attraction: scientists from 38 different nationalities

- Italy: 31
- Germany: 18
- Argentina: 12
- France: 11
- USA: 9
- Belgium: 7
- Brazil: 7
- Venezuela: 6
- Iran: 5
- Poland: 5
- Korea: 3
- UK: 3
- Greece: 3
- Hungary: 3
- Russia: 3
- Cameroon: 2
- China: 2
- Estonia: 2
- Japan: 2
- Mexico: 2
- Portugal: 2
- Ukraine: 2
- 15 other countries: 1
COMPLEX SYSTEMS: STATISTICAL AND NONLINEAR PHYSICS

- TRANSPORT AND INFORMATION IN QUANTUM SYSTEMS
- NONLINEAR PHOTONICS
- NONLINEAR DYNAMICS IN FLUIDS
- BIOCOMPLEXITY
- COLLECTIVE PHENOMENA IN SOCIAL AND SOCIO-TECHNICAL SYSTEMS

Associated Unit: UIB Group on Human Cognition and Evolution
# IFISC RESEARCH LINES

<table>
<thead>
<tr>
<th>IFISC RESEARCH LINES</th>
<th>Pere Colet</th>
<th>Víctor M. Eguíluz</th>
<th>Ingo Fischer</th>
<th>Damia Gomila</th>
<th>Emilio Hernández-Garcia</th>
<th>Cristóbal López</th>
<th>Rosa López</th>
<th>Manuel Matías</th>
<th>Sandro Meloni</th>
<th>Claudio Mirasso</th>
<th>José J. Ramasco</th>
<th>David Sánchez</th>
<th>Maxi San Miguel</th>
<th>Llorenç Serra</th>
<th>Tomàs Sintes</th>
<th>Raúl Toral</th>
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Information Processing (IP) in and by Complex Systems

**IN**

**PUT**

**OU**

**TP**

in: Processing, transmission, storage and retrieval of information in complex systems.

by: Designed information processing and sensing.
Complex Systems Science
Synthesize novel methods connecting the know-how of the individual fields.

Quantum information processing

Bio-Complex Systems

Machine learning/brain (-inspired) computing concepts

Socio-technical Systems

Big-data analysis

Complex Networks Theory
María de Maeztu Unit of Excellence: Objectives

L1: Information processing in biological systems

• Information processing in biochemical networks, brain circuits and structures, and ecological networks
• Genetic diversity in ecosystems and its response to environmental changes
• Biodiversity patterns, especially in microbial communities; alternative ways to encode and store information

L2: Brain-inspired analog computing in photonic and electronic systems

• Hardware implementations of reservoir computing and their applications in telecom and datacom
• Autonomous operation of recurrent networks
• Development of novel computing concepts, theoretical framework for scaling and

L3: Quantum information: decoherence, dissipation, and transmission

• Emergent quantum phenomena and information retrieval in extended and network systems
• New functionalities based on nanoelectronic devices
• Information processing using quantum materials

L4: Information processing in socio-technical systems

• Evolution of social-system and processing of information: opinion, consensus, meme spreading, fake news, etc.
• Studies of mobility of people and animals;
• Data-driven modeling and response of urban systems to external perturbations.
Our seminars are webcast live

http://ifisc.uib-csic.es/live.php

383 webseminars 2009-17
Publications


High impact 2012-2018:
1 Rev. Mod. Phys,
4 PNAS,
4 Nature Comm,
1 Nature Geophysics

JOURNALS WITH THE LARGEST NUMBER OF PUBLICATIONS

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IFISC PUBLICATIONS 2013-2018

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2013
2014
2015
2016
2017
2018
TOTAL
98
71
72
64
72
75
452
Contributions outside traditional basic physics (2013-18):
61 + IEEE(14)


Pioneering role in opening new cross-disciplinary research fields.

Publications in top physics, multidisciplinary and non-physics journals (Biology, Ecology, Neuroscience and Social Sciences).

- Citation per paper in 2012-17: 11.66
  (Max Planck Dresden: 11.53; ISC(CNR, Italy): 8.88)
Grand total budget of active projects in 2018: 2,284,475 €

Budget of EC-funded active projects in 2018: 34 % of total

Maria de Maeztu Unit of Excellence
Spanish National Science Plan projects
(areas: Physics, ICT, Marine Sciences, Material Sciences)

Granted projects 2015-19: 12

European Commission Framework Program projects:

Granted projects 2015-18: 4 + 1 contract

Collaboration Networks:

EC COST actions, Spanish representative in Management Committee:

Running COST actions 2015-18: 3
Granted COST actions 2015-19: 1

Spanish Plan funded networks:

Granted networks 2015-18: 6 +1 (SOMMa)

Research contracts (private funding): 7 contracts in 2015-18
Spanish National Science Plan (MINEICO)

**SET@QT:** Spintronics, Energy, and Topology @ Quantum Transport (2015-17) PI. R. López

**NOMAQ:** Non-Markovian quantum evolutions in structured environments (2015-17). PI. R. Zambrini

**QuStruct:** Quantum information preserving with structured embeddings (2016-17) PI. F. Galve

**EPHEQUCS:** Emergent Phenomena and Decoherence in Quantum Complex Systems (2017-2019) PI. R. Zambrini

**IDEA:** Improving data DEcoding in optical communication networks All-optically using neuro-inspired photonic systems (2017-2019) PI. I. Fischer, C. Mirasso

**ESOTECOS:** Emergent Social, Technological and Ecological Complex Systems (2016-18). PI. P. Colet, M. San Miguel

**LAOP:** Lagrangian studies of Oceanic Processes: connectivity patterns, barriers to transport and marine populations (2016-18) PI. C. López

**SPASIMM:** Spatiotemporality in sociobiological interactions, models and methods (2017-2019) PI. V. M. Eguíluz

**TQM@Nano:** Transport in Quantum Materials at the Nanoscale (2018-2020) PI. D. Sánchez, R. López
Spanish National Science Plan (MINEICO)

**PACSS:** Physics approach to complexity in sociotechnical systems (2019-21)
PI. R. Toral, J. Ramasco

**SuMaECO:** Sustainability of marine coastal ecosystems in the context of global change in the Mediterranean sea: Modeling and simulations (2019-21).
PI. D. Gomila
EUROPEAN COMMISSION

**LINC:** Learning about Interacting Networks in Climate (2012-15) PI. E. Hernández-García

**Complex World:** Analysis of air transportation using complex networks, EC-SESAR-Eurocontrol (2011-15). PI. M. San Miguel

**EUNOIA:** Evolutive User-centric Networks for Intraurban Accessibility (2012-15) Coordinator and PI. M. San Miguel

**LASAGNE:** Multi-Layer Spatiotemporal Generalized Networks (2012-15) PI. M. San Miguel

**INSIGHT:** Innovative Policy Modelling and Governance Tools for Sustainable Post-Crisis Urban Development (2013-16) PI. J. Ramasco

**TREE:** Data-driven modelling of network-wide extension of the Tree of REactionary delays in ECAC área (2013-16) PI. J. Ramasco

**QuProCS:** Quantum Probes for Complex Systems, H2020, (2015-17) PI R. Zambrini

**BIGDATA4ATM:** Passenger-centric Big Data Sources for Socio-economic and Behavioural Research in ATM, H2020 (2016-18) PI. J. Ramasco

**CENTURION:** Signal proCEssing in optical communication NeTworks Using Reservoir Computing, H2020 MSCA IF (2016-18) PI I Fischer

**CAFE:** Climate Advanced Forecasting of sub-seasonal Extremes (2018-23) PI. E. Hernández-García

**ESPON EGTC :** Big data for territorial analysis and housing dynamics (2018) PI. J. Ramasco
COLLABORATION NETWORKS (2014-18)

EC COST actions:


Spanish National Plan collaboration networks:

**COMSOTEC**: Complex Sociotechnical systems (2015-17) M. San Miguel

**IBERSINC**: Dynamics and synchronization in complex networks (2016-17) M.C. Soriano

**RFE2017**: Network of non-equilibrium statistical physics and its multidisciplinary applications (2017-19) D. Sanchez

**TNT**: Thermoelectricity network: new theories (2017-19) R. López

**RICTE**: Quantum Information and Technologies network (2017-19) R. Zambrini

**SOMMa Alliance**: The ‘Severo Ochoa’ Centres and ‘María de Maeztu’ Units of Excellence Alliance (2018-2022) C. Mirasso
**BILATERAL INTERNATIONAL COLLABORATIONS**

**ND-PHOT:** Nonlinear Dynamics in photonics for future information and communication technologies (2016-2018). PICS CNRS (Bensançon)-CSIC (IFISC). D. Gomila

**MOREHOUSE:** Modeling housing markets dynamics thanks to emerging and heterogonous data sources (2019-2021). PICS CNRS (Institute for Humanities and Social Sciences, Paris)-CSIC (IFISC) J. Ramasco.

**IN-TREE:** Intersdisciplinary and Transdisciplinary Studies in Ecology and Evolution (2016-2022) CNPq, CAPES, FAPESB Brazil. E. Hernández-García

**Collaborations with International Organizations:**

- **UNWTO:** World Tourism Organization
- **UNICEF:** Data, Research and Policy (DRP)

Migrant mobility flows
PRIVATE FUNDING (2015-18)


LOGITRAVEL: Research contract on Data Analysis with LOGITRAVEL (2015). PI. J. Ramasco and P. Colet


CAASE: Coupled Animal and Artificial Sensing for Sustainable Ecosystems, King Abdullah University of Science and Technology (2016-18), PI. V.M. Eguiluz


TEAMS: Towards an Ecological Approach of Information Systems (Fondazione Cassa di Risparmio di Padova e Rovigo (2018), PI S. Meloni
IFISC Business Links

Contracts

Xarion
nuubo®
SESAR
EUROCONTROL
KAUST
Isdefe
Fondazione

Joint Projects

NOMMON
BBVA
INNOVATION CENTER
orange
Telefónica

Kineo
SThAR
2GN
iBit

LOGITRAVEL.com
altair
Biolinea|com
**SURF @ IFISC FELLOWSHIPS**

- **Summer Undergraduate Research Fellowships**
- **Shared PhD program of excellence in Physics of UIB**
- **Summer schools**

Master’s Degree in Physics of Complex Systems

The Master in Physics of Complex Systems is an official degree offered by the University of the Balearic Islands (UIB) in collaboration with the Spanish National Research Council (CSIC). It is organized and taught by IFISC, the Institute for Cross-Disciplinary Physics and Complex Systems, a joint UIB-CSIC research center in Palma de Mallorca, Spain.
**IFISC WORKSHOPS**

- **CEWQO**
  - 25th CENTRAL EUROPEAN WORKSHOP ON QUANTUM OPTICS
    - May 21-25, 2018
  - IFISC 10y CROSSROADS IN COMPLEX SYSTEMS
    - June 5-8, 2017
  - QUANTUM PROBES FOR COMPLEX SYSTEMS
    - April 6-7, 2017
  - MAJORANA STATES IN CONDENSED MATTER: TOWARDS TOPOLOGICAL QUANTUM COMPUTATION
    - May 14-20, 2017
  - YOUNG RESEARCHERS AT THE CROSSROADS
    - June 2-4, 2017
  - COSTNET WORKSHOP ON STATISTICS OF NETWORK DATA SCIENCE
    - October, 2017
  - ICE-3 QUANTUM INFORMATION IN SPAIN
    - April 13-15, 2016
  - 2nd QUANTUM THERMODYNAMICS CONFERENCE
    - April 19-24, 2015

**EXPLORATORY WORKSHOPS**

- QUANTUM CONTROL IN COMPLEX NETWORKS
  - January 2018
- NEW TRENDS IN FREQUENCY COMB GENERATION
  - November, 2017
- TREE: DATA-DRIVEN MODELLING OF NETWORK-WIDE EXTENSION OF THE TREE OF REACTIONARY DELAYS IN ECAC AREA
  - January, 2014
- WORKSHOP THEfoDA: THEORY AND MECHANISMS OF SOCIAL INTERACTIONS IN THE BIG DATA ERA
  - February, 2013

**IFISC SUMMER SCHOOLS**

- VII and VIII SUMMER SCHOOL ON STATISTICAL PHYSICS OF COMPLEX AND SMALL SYSTEMS
  - June 19-30, 2017
  - July 2-13, 2018
- SUMMER SCHOOL ON COMPLEX SOCIO-TECHNICAL SYSTEMS
  - September 4-8, 2017
- RICE SCHOOL
  - April 11-12, 2016
Complex systems are characterized by emergent and collective phenomena of many interacting units. Fundamental understanding of these systems comes from Statistical Physics together with the Theory of Dynamical Systems, which includes the study of chaos and the effect of fluctuations and random events on systems evolution.

This research line of exploratory nature is the backbone of IFISC: We develop new concepts and methods for the study of Complex Systems, and we analyze generic phenomena such as synchronization, phase transitions, nonequilibrium instabilities, spatiotemporal pattern formation, and the dynamics and evolution of complex networks.
COMPLEX SYSTEMS. STATISTICAL AND NONLINEAR PHYSICS

Research projects:

- **ESoTECoS**
  Emergent Social, Technological and Ecological Complex Systems
  PI. P. Colet, M. San Miguel

- **EPheQuCS**
  Emergent phenomena and decoherence in quantum complex systems. PI. R. Zambrini

- **SPASIMM**
  Spatiotemporality in sociobiological interactions, models and methods. PI. V. M. Eguíluz

- **IDEA**
  Improving Data Decoding in optical communication networks all-optically using neuroinspired photonic systems. PI. I. Fischer

- **PACSS**
  Physics approach to complexity in sociotechnical systems. PI. R. Toral, J. Ramasco

- **SuMaECO**
  Sustainability of marine coastal ecosystems in the context of global change in the Mediterranean sea: Modeling and simulations. PI. D. Gomila
Understanding of Quantum Complex Phenomena plays a key role in the development of Quantum Technologies identified as one of the most strategic areas for future research and innovation.

In this research line, we are devoted to questions related to quantum transport for charge (nanoelectronics), spin (spintronics), energy (thermoelectrics) and information (quantum correlations), with a particular focus on nanostructures.

Moreover, we investigate decoherence effects in complex environments, explore quantum probing, and emergent phenomena such as synchronization, with a focus on quantum correlations and thermodynamics and their impact on information processing.
TRANSPORT AND INFORMATION IN QUANTUM SYSTEMS

Research projects:

- **QuProCS**
  Quantum Probes for Complex Systems  
  PI. R. Zambrini

- **SET@QT**
  Spintronics, Energy, and Topology @ Quantum Transport  
  PI. R. López

- **NOMAQ**
  Non-Markovian quantum evolutions in structured environments  
  PI. R. Zambrini

- **EPheQuCS**
  Emergent phenomena and decoherence in quantum complex systems  
  PI. R. Zambrini

- **TQM@Nano**
  Transport in Quantum materials at the Nanoscale  
  PI. D. Sanchez and R. López
Within this line of research, we explore complex phenomena in photonics, filling the gap between Modern Photonic Sources and Functional Complex Systems.

Our Nonlinear Photonics Lab, working alongside a strong theoretical team, aims to gain an in-depth understanding of complex phenomena and to provide novel solutions from communication to information processing, transferring knowledge to the Information and Communication Technologies (ICT) domain.

We study nonlinear and spatio-temporal emission properties of semiconductor lasers, implement optical complex networks based on lasers, advance characterization techniques, and demonstrate the utility of optical complexity for information technologies including encryption and ultra-fast neuro-inspired photonic information processing.
NONLINEAR PHOTONICS

Research projects:

- **IDEA**
  Improving data Decoding in optical communications networks All-optically using neuro-inspired photonic systems
  PI. I. Fischer, C. Mirasso

- **NeuroQNet**
  Neuromorphic Computing using Quantum Dot-Networks
  PI. I. Fischer

- **CENTURION**
  Signal proCEssing in optical communication NeTworks Using ReserVoIcOmputiNg
  PI. I. Fischer

- **ND-PHOT**
  Nonlinear dynamics in photonics for future information and communication technologies
  PI. D. Gomila

Pere Colet
Ingo Fischer
Damià Gomila
Claudio Mirasso
Fluid flows occur in a huge range of scales, from blood capillaries to atmospheric weather systems. The way in which substances are transported has large impacts, e.g., on how pollutants arrive to distant locations, plankton meets the nutrients, or into the whole heat balance involved in the Earth climate.

At IFISC we develop techniques useful to characterize transport in fluids, quantify stretching, mixing, and connectivity between parts of a fluid. We apply them to geophysical settings, mostly in the ocean. We develop tools to identify barriers to the transport of oxygen and nutrients, evaluate the ecological implications of larval transport, or track the origins of water vapor masses transported by atmospheric winds.
NONLINEAR DYNAMICS IN FLUIDS

Research projects:

-LAOP
Lagrangian studies of Oceanic Processes: connectivity patterns, barriers to transport and marine populations
  PI. C. López

-LINC
Learning about Interacting Networks in Climate
  PI. E. Hernández-García

-CAFE
Climate Advanced Forecasting of sub-seasonal extremes
  PI. E. Hernández-García
Living systems are the paradigm of complex systems, with nonlinear interactions occurring at all spatial and temporal scales, from molecules and genes to the planetary scales defining the global biosphere.

One of the focus of our research is the ecological level where we consider modes of organisms’ mobility and their interplay with food search, disease propagation, spatial patterning, and also with the basic ecological interactions such as competition, predation, or mutualism.

Another focal issue in our studies is understanding brain function, which requires approaches at scales that range from individual neurons to the whole brain. At the neuronal level, we concentrate on aspects of synchronization between interacting neuronal populations and study how information flows. With the help of statistical measures, we analyze experimental data and compare the results with neuronal models.
BIOCOMPLEXITY

Research projects:

- **ESoTECoS** Emergent social, technical and ecological complex systems. PI P. Colet, M. San Miguel

- **CAASE** Coupled Animal and Artificial Sensing for Sustainable Ecosystems: The Red Sea as a case Study. PI. V. Eguíluz

- **SPASIMM** Spatiotemporality in sociobiological interactions, models and methods. PI. V. M. Eguíluz, K. Klemm

- **SuMaECO** Sustainability of marine coastal ecosystems in the context of global change in the Mediterranean sea: Modeling and simulations. PI. D. Gomila

- **IN-TREE** NCT in Interdisciplinary and Transdisciplinary Studies in Ecology and Evolution. PI. E. Hernández-García
Social systems are prominent examples of Complex Systems, emergent phenomena, and the Micro-Macro paradigm. Today’s main societal changes and challenges arise from the feedback loop that entangles society with Information and Communication Technologies (ICT) as a prototypical socio-technical system.

In this line of research we develop new concepts, tools and models aiming at identifying generic mechanisms underlying collective phenomena in these systems. We do this in the framework of Computational Social Sciences with the use of Game Theory, Statistical Physics, Agent Based Models, Complex Networks Theory, and Big Data analysis. We study phenomena such as opinion formation, cooperation, cultural conflicts, language competition and social learning. Moreover, we focus on ICT data-driven research on socio-technical systems, addressing problems of human mobility, transportation, tourism, city science, epidemics, and energy consumption.
COLLECTIVE PHENOMENA IN SOCIAL AND SOCIO-TECHNICAL SYSTEMS

Research projects:

**-EUNOIA**
Evolutive User-centric Networks for Intraurban Accessibility
PI. M. San Miguel

**-INSIGHT**
Innovative Policy Modelling and Governance Tools for Sustainable Post-Crisis Urban Development
PI. J. J. Ramasco

**-TREE**
Data-driven modelling of network wide extension of the tree of reactionary delays in ECAC area
PI. J. J. Ramasco

**-BigData4ATM**
Passenger-centric BigData Sources for Socio-economic and Behavioural Research in ATM
PI. J. J. Ramasco

**-ESoTECoS**
Emergent social, technical and ecological complex systems
PI P. Colet, M. San Miguel

**-PACSS**
Physics approach to complexity in sociotechnical systems.
PI. R. Toral, J. Ramasco

**-ESPON EGTC + MOREHOUSE**
Big data for territorial analysis and housing dynamics
PI. J. J. Ramasco
2015 International Year of Light
Laser Graffiti
Walls of Palma

Science Fairs

Festival Pint of Science
Palma de Mallorca
15-17 MAYO

Mini-Solar Car Race in Palma
World Environmental Day
4,200 visitors, Casal Solleric

2015 International Year of Light

Philip Ball
LOCAL AND NATIONAL MEDIA IMPACT

Un estudio desvela cómo se forman círculos vacíos en la posidonia

La competencia entre las plantas por los recursos existentes es la responsable de los llamados “círculos de hadas”, unos claros circulares sin vegetación que se forman en las praderas de posidonia oceanica, según revela un estudio que puede contribuir a su conservación.

Señales caóticas como herramienta de encriptación

La Almudaina
Se cumplen una década del creación del Instituto de Física Interdisciplinar y Sistemas Complejos (IFISC) de la UIB.

Focos, ballenas y aves marinas hacen los mismos viajes por el océano

El cable submarino podría haber implicado propagar el apagón de Menorca a partir de Mallorca, según científicos
May, 2019

Facebook: 994 followers

Twitter: 1,621 followers

YouTube: 121,566 visualizations
756 subscribers
512 videos