

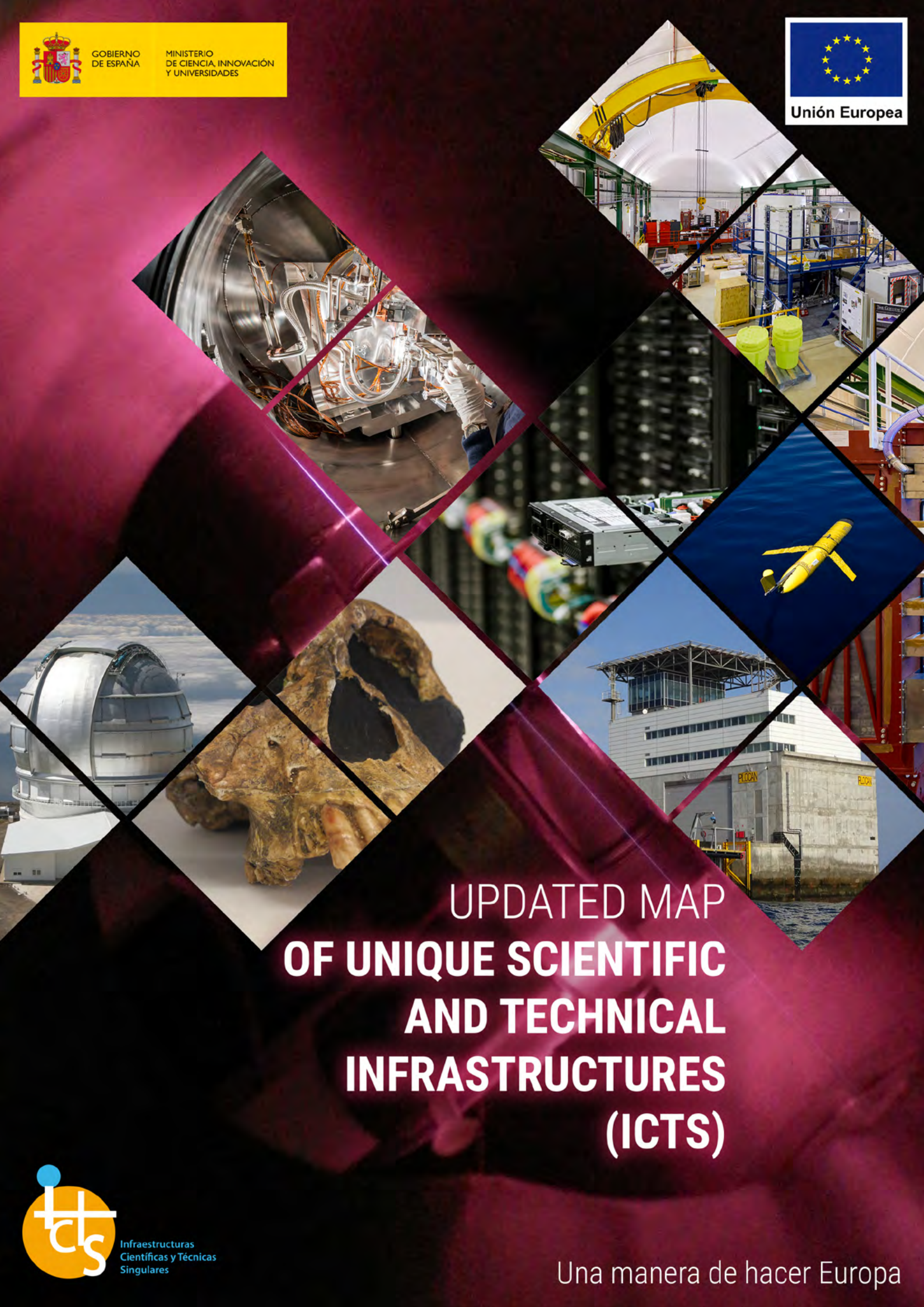


GOBIERNO  
DE ESPAÑA

MINISTERIO  
DE CIENCIA, INNOVACIÓN  
Y UNIVERSIDADES



Unión Europea



# UPDATED MAP OF UNIQUE SCIENTIFIC AND TECHNICAL INFRASTRUCTURES (ICTS)



Infraestructuras  
Científicas y Técnicas  
Singulares

Una manera de hacer Europa

UPDATED MAP  
**OF UNIQUE SCIENTIFIC  
AND TECHNICAL  
INFRASTRUCTURES  
(ICTS)**



## PRELUDE

In 1986 Spain took the important step of passing the first science law in its history. It was a time of opening for Spain, in which it became a Member State of the European Union, a time of eagerness for society in general and the research community in particular. Thanks to the enthusiasm and hard work of many people, the groundwork was laid during that time for what is today the Spanish System of Science, Technology, and Innovation. In the more than three decades that have transpired since then, the number of researchers has multiplied, scientific production has surged, highly competitive research centers have opened, and companies able to tackle first-class technological challenges in many fields have emerged.

These achievements have come hand in hand with the construction of the instruments necessary to carry out top-notch research. The result is this Map of Unique Scientific and Technical Infrastructures (ICTS), made up of supercomputers,

telescopes, cleanrooms, biomedical technologies, underground laboratories, synchrotrons, particle accelerators, advanced lasers, biological reserves, solar, oceanic and hydraulic platforms, oceanographic research ships, and polar bases in Antarctica. A total of 29 ICTS, made up of 62 nodes, allow for ambitious research projects that attract first-rate talent and enhance the technological and innovative capacity of Spanish companies.

The current map includes Spain's principal science and innovation infrastructures. It was approved on November 6, 2018 by the Council of Science, Technology, and Innovation Policy, a general coordination body for scientific and technical research in Spain that is made up of 10 ministries with responsibilities in R&D, as well as the Autonomous Communities.

Promoting science and innovation is the best engine for sustainable economic growth and long-term social wellbeing.

Spain needs to invest more in research and innovation and facilitate the work of researchers. We also need to continue supporting the key facilities described in this book and increasing our participation in large scientific infrastructures worldwide. Only through a strong commitment to science will we be able to consolidate Spain as a knowledge and innovation powerhouse that is capable of facing the future with guarantees of success.

The Unique Scientific and Technical Infrastructures described in this book are crucial for Spain and its science, technology, and innovation. I encourage you to browse the pages of this book and discover the state-of-the-art infrastructures that represent the scientific and technological capacity that exists in Spain today. You won't regret it.





# FOREWORD

The high quality of the scientific and technological labour produced in our country is the main reason why it can be claim that Spain is a country of research, development and innovation. For this to be the case, and continue to be so, it is essential to have infrastructures that provide researcher's community with the possibility of accessing state-of-the-art technology that facilitates the path to cutting-edge research.

In this sense, our country has the so-called Unique Scientific and Technical Infrastructures (Infraestructuras Científico-Técnicas Singulares in Spanish) organized in what is known as the ICTS Map. Access to these infrastructures allows us to use cutting-edge technology, acquire highly specialized training, attract scientific and technological

talent and foster R&D&I, both in public and business fields. All of this is essential for the evolution of our society.

Since the first ICTS Map release, these infrastructures have proven to be a fundamental asset in the Spanish R&D&I system, as they provide a type of technology that, due to its size, economic cost, location and / or uniqueness, cannot be available at each research centre.

The ICTS Map includes scientific and technological facilities, unique in its kind and with a high investment, maintenance and operation cost that the Central Administration and the Autonomous Communities sustain in an exercise of public share responsibility, with the aim of avoiding duplication, strengthening ICTS

capacities and promoting its industrial use. This Map is regularly updated by an experts evaluation panel, which considers criteria of maximum scientific, technological and innovation quality.

I encourage you to browse this book showing the last Map update. These pages not only enclose brief information of each ICTS but also illustrate some of the results obtained with them highlighting their importance for the advancement of knowledge and the benefits brought to society.

**RAFAEL RODRIGO MONTERO**

Secretario General de Coordinación de Política Científica

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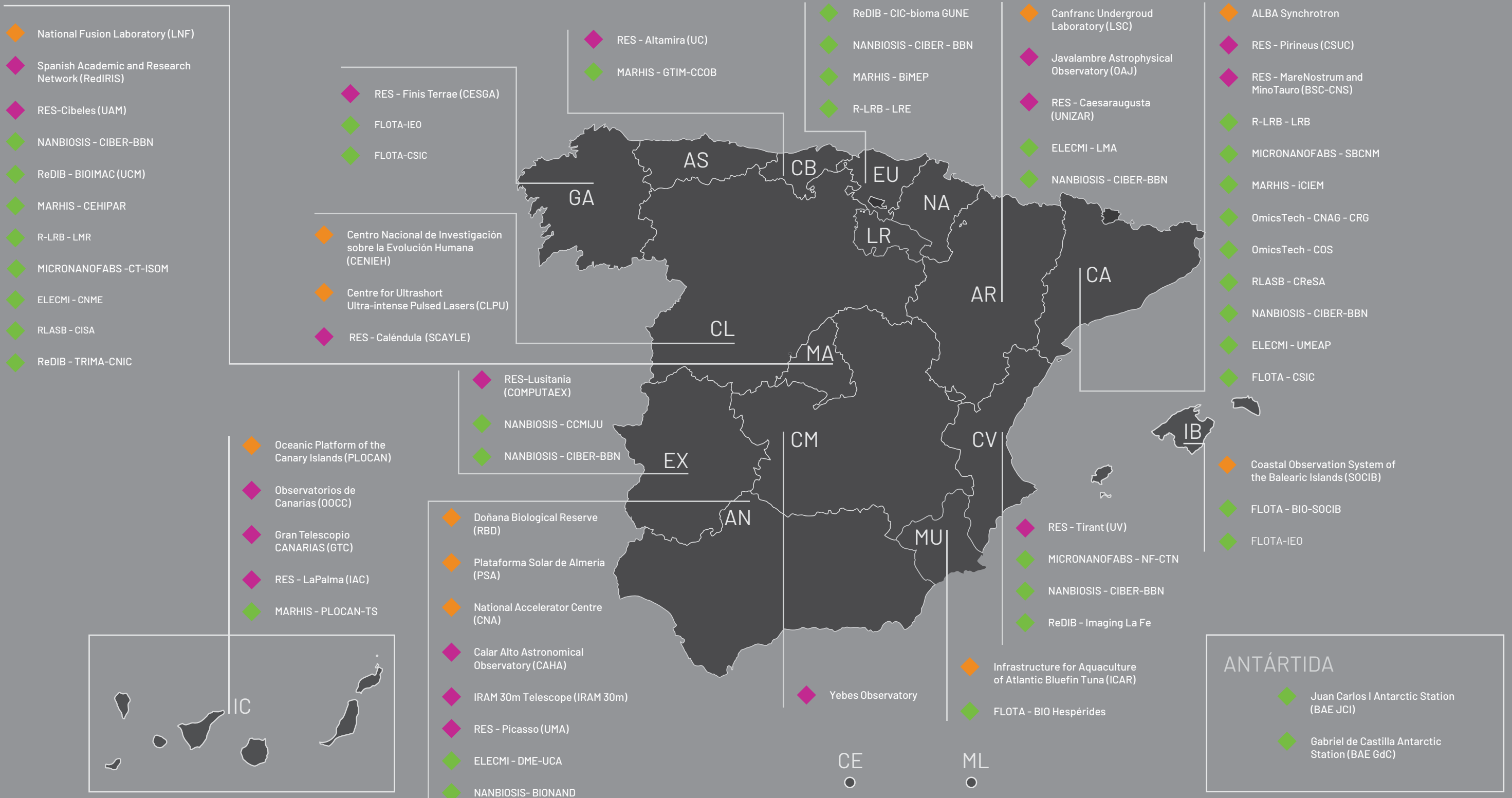
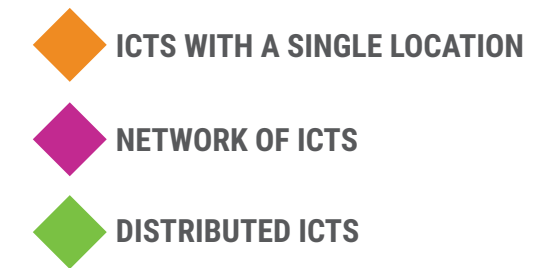
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# UPDATED MAP OF UNIQUE **SCIENTIFIC AND TECHNICAL INFRASTRUCTURES (ICTS)**

## ICTS STRUCTURE







@UTM\_CSIC

## INTRODUCTION





# INTRODUCTION

The term **Unique Scientific and Technical Infrastructures (ICTS)** refers to leading R&D facilities that, individually or by coordinating several installations, provide services for pioneering and top-quality research, as well as for the transmission, exchange and preservation of knowledge, transfer of technology, and promotion of innovation. The ultimate goal is to provide the national and international science, technology and industrial community with pioneering scientific-technical infrastructures that are essential for competitive and quality scientific and technical research. These are technical means that are unique or exceptional in their field, with a high investment and/or maintenance and operation cost, and whose importance and strategic nature justify their availability for the entire R&D group.

The ICTS have three fundamental characteristics:

- they are **publicly owned infrastructures**. That is, they belong to or are managed by public entities under the authority of the state and/or regional governments. They are mostly funded by public money.
- they are **unique**, which means they are one of a kind, including:
  - Large facilities that enable the observation, analysis and interpretation of phenomena of interest.
  - Complex experimental infrastructures designed to create, reproduce and study physical, chemical and biological phenomena of interest.
  - Large experimental infrastructures for engineering and developing new technologies applied in different fields.
  - Essential infrastructures to provide scientists with access to natural settings that present unique characteristics for research.
  - Advanced technology that provides horizontal and fundamental support

in all scientific and technological disciplines.

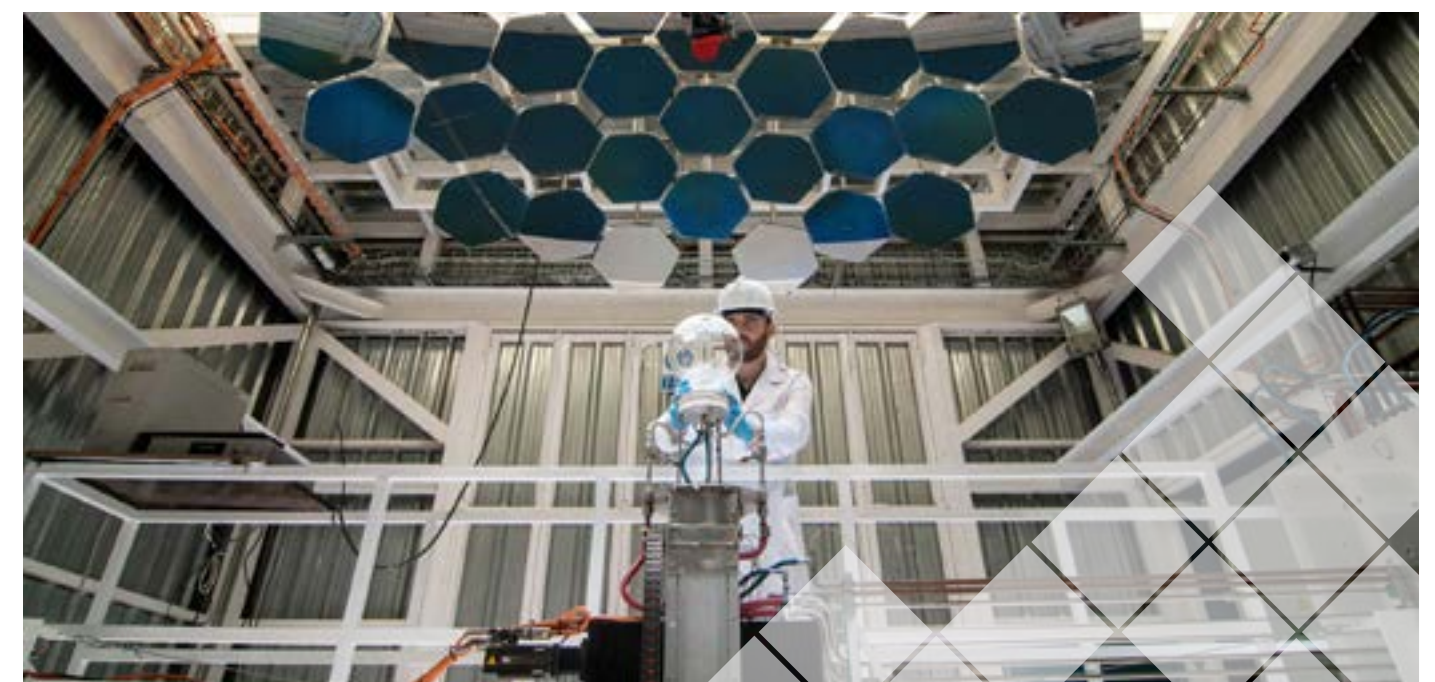
- they are **open to competitive user access** in the entire research community, both from the public and private sector.

The ICTS are located across Spain and are included on the "National Map of Unique Scientific and Technical Infrastructures (ICTS)" (hereinafter "ICTS Map"). The first map was approved at the 3rd Conference of Presidents held on 11 January 2007, and was created with the participation of the Autonomous Communities. Since then, this map has been regularly reviewed and assessed, and the update is part of the mandate established in the "Spanish Strategy for Science, Technology and Innovation 2013-2020", which was approved by the Council of Ministers on 1 February 2013. In 2014, an update that was valid until **6 November 2018 was approved. This was the date on which the Scientific, Technological and Innovation Policy Council (CPCTI) approved the current map, which consists of 29 ICTS, bringing together a total of 62 infrastructures.**

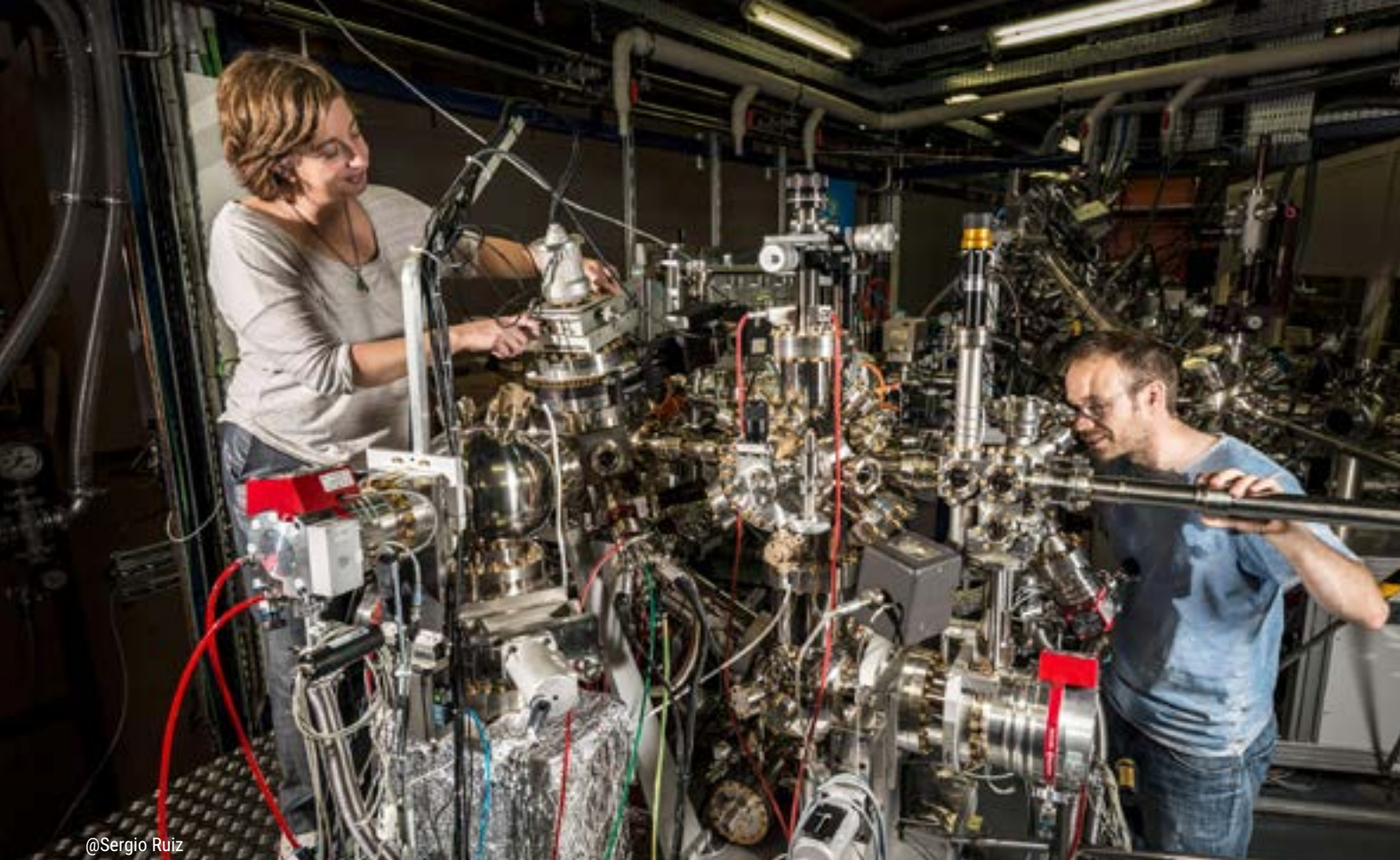
## NATIONAL CONTEXT

There is a clear relationship between a country's capacity to generate knowledge and innovation and its socio-economic competitiveness and development. That is why the science, technology and innovation policies are a fundamental element in the development of modern societies. Just like neighbouring countries, the Spanish government plans these policies regularly. Article 149.1.15 of the Spanish Constitution lists promotion and general coordination of scientific and technical research as one of the exclusive competences of the State.

The **«Spanish Strategy for Science, Technology and Innovation 2013-2020»** is the leading strategic framework for the whole country regarding research, technology and innovation and it considers the deployment of the "ICTS Map" to be key for the national development of the Spanish System of Science, Technology and Innovation, together with its inclusion in the European Research Area. Scientific and technical research excellence must be supported by an advanced network of scientific-technical infrastructures and facilities, and







@Sergio Ruiz

provide access to top-level international infrastructures, as is the case with the ICTS. Access to advanced scientific and technical infrastructures is one of the most important assets when it comes to remaining as a leader in research, increasing the specialised training capacity in R&D activities and capturing talent.

The outline of the scientific policy included in the strategy mentioned above is focused on state plans. In that respect, the **“Spanish National Plan for Scientific and Technical Research and Innovation”** for 2017–2020 lists the consistent use of six coordination mechanisms, referring to the adoption of management principles and instruments that lead to coordinated action in the activities of public administrations. The first of these calls on all public administrations to share responsibility in achieving the objectives and to be committed to the main priorities that have been established. This includes implementing joint programming instruments and co-financing tools that

encourage the development and consolidation of the System's capacities and the scientific, technological and business leadership of its agents, without forgetting the co-financing of the ICTS based on scenarios consistent with the scientific and technological evolution of these ICTS and the established possibility of borrowing.

#### EUROPEAN AND INTERNATIONAL CONTEXT

Other important aspects for the update of the ICTS Map come from the European context, in particular from the current EU Research and Innovation Programme 2014–2020 (**Horizon 2020**), the ESFRI Roadmap, and the current 2014–2020 programming period of the European Regional Development Fund(ERDF).

As part of the “Excellent Science” pillar, the EU's H2020 R&D Framework Programme includes the actions supporting scientific infrastructures with the aim of reinforcing and extending European scientific excellence and consolidating the European Re-

search Area(ERA) to ensure the EU's science system is more competitive on a global scale. The general objectives of the H2020 regarding research infrastructures are as follows: (i) To optimise the use and development of European scientific infrastructures; (ii) To promote their human potential and potential for innovation; and (iii) To reinforce the coherence of national and European policies in terms of infrastructures.

One of the new aspects of the H2020 has been reinforcing the role of ex-ante assessment. This assessment is one of the requirements for receiving European funds and is actually a prior and exhaustive scheduling of the activities in which each of the Member States expects to invest these funds. Updating the ICTS Map was the tool used to comply with the ex-ante assessment relating to the investment priority of the **European Research Development Fund (ERDF)**: “Enhancing research and innovation infrastructure (R&I) and capacities to develop R&I excellence and promoting centres

of competence, in particular those of European interest” It has also been coordinated with the Regional Research and Innovation Strategies for Smart Specialisation (RIS3) from the Autonomous Communities, which are tools to help the regions propose and make optimal choices for their prosperity. As a consequence of this, the ICTS will be able to benefit from co-financing by the ERDF over the 2014–2020 programming period.

Furthermore, the ICTS are aligned with the European Strategy Forum on Research Infrastructure (ESFRI) and with other international strategic plans in specific fields, including those in the agendas of the European Technology Platforms, the Joint Technology Initiatives (JTI), Joint Programming Initiatives (JPI), etc. This promotes and ensures the scientific and technological competitiveness of Spanish infrastructures on the international stage, especially with regard to the ICTS.

#### CONFIGURATION OF THE ICTS MAP

The Scientific, Technological and Innovation Policy Council (CPCTI), formed on 18 September 2012, is the general coordination body of scientific and technical research in Spain, and is made up of representatives from the Spanish government and the Autonomous Communities. One of

its roles has been to approve the update of the 2017–2020 ICTS Map in order to achieve the following objectives:

- **To consolidate the ICTS Map** as a long-term planning and development tool for this type of infrastructure, updating it in accordance with the established criteria with an emphasis on scientific-technical and economic quality and sustainability, prioritising the continuation of operating facilities and others that have viable financing scenarios for the State and the Autonomous Communities, and implementing it jointly with the entities and administrations involved.
- In support of the ICTS, **to plan the optimal application of national, regional and European funding** to acquire a stable, medium-term funding framework that guarantees the achievement of its objectives.
- **To establish the foundations to drive the medium-term achievement of the following objectives:**
  - To provide public and private sector users with access to the ICTS and optimise their use through competitive, public and transparent open-access mechanisms, thereby encouraging greater openness of the ICTS to users from the

international scientific and technological communities.

- To drive innovation, transfer of technology and private sector participation and investment in the ICTS through Public Procurement of Innovation, the science industry and sponsorship.
- To ensure the scientific and technological competitiveness of Spanish infrastructures on the international stage, and encourage their internationalisation. In particular, the connection between the ICTS and European infrastructures will be promoted.
- To monitor the volume, efficiency and quality of the returns to the society from ICTS, in order to improve the use of profits and inform society of the benefits that come from the ICTS.

Stated briefly, the renewal process of the ICTS Map started with the CPCTI defining the objectives and principles that the participating infrastructures should achieve and follow. Furthermore, an update procedure for the Map was established and the **Advisory Committee on Unique Infrastructures (CAIS)** was formed as a Work Group of the Executive Committee of the CPCTI. After a thorough analysis and assessment process of the strategic plans presented by the







applying infrastructures, in which the Spanish National Agency for Assessment and Forecasting (ANEP) took part with international experts, the CAIS generated a proposal for the configuration of the new Map. Finally, the CPCTI approved the Map of Unique Scientific and Technical Infrastructures (ICTS) on 6 November 2018.

The ICTS can be located in **a unique location (infrastructure with a single location)**, can be part of a **Network of Infrastructures (RI)** or can be formed as a **Distributed Infrastructure (ID)**, depending on the level of integration and coordination of its capacities. The ICTS Map is also dynamic and open in the sense that the infrastructures included in the current Map must continue to meet the requirements in order to keep their ICTS status, and on the other hand, it is open to the inclusion of other infrastructures that demonstrate compliance with these requirements.

The requirements that a facility must comply with in order to be considered an ICTS, in any of the ways stated above, are formally defined in the CPCTI document, which accompanies the configuration of the current ICTS Map. Summarised, these requirements are the following:

- **Unique and strategic** - An ICTS is a unique infrastructure, an experimental cutting-edge tool unique in Spain for its content and features, open to the entire R&D&I system of our country, scientifically and technologically advanced, essential for carrying out specific technological research and/or development.
- **Objectives** - As mentioned above, they should be aligned with the objectives of the Spanish Strategy for Science, Technology, and Innovation, the State Plan for R&D&I and with the corresponding European and international programmes.

- **Investment** - They entail a high investment cost in scientific and technological infrastructure on its construction, updating and improvement (from €10 million of accumulated investment on technological assets), as well as in their maintenance and operation.

- **Open access** - The ICTS should apply a competitive open-access policy for the scientific, technological, and industrial communities, as well as government administrations. There should be a demonstrable and proportionate demand for use or access from the national and international community. This access will be assessed and prioritised with criteria of excellence and scientific-technical viability.

- **Scientific and Technical Advisory Committee** - In general, unless the specific nature of the infrastructure discourages it, the scientific-

technological activities and strategies of the ICTS should be assessed by a Scientific and Technical Advisory Committee of international importance.

- **Management** - The ICTS will have suitable management systems in accordance with its specific characteristics, particularly relating to the infrastructures and services offered competitively and to support users.
- **Strategic Plan** - The ICTS should have a quadrennial Strategic Plan that is reviewed regularly, and which establishes the objectives, strategies and resources.
- **Production and Performance** - The production and performance of the ICTS should be proportionate to the cost and size of the facility. Every ICTS should keep a Record of R&D&I Activities, which includes the access offered, projects and activities carried out, and the R&D results from the use of the facility (publications, patents, etc.).

The ICTS Map covers a wide range of scientific fields, and the same infrastructure can

provide services for different scientific disciplines at the same time.

From an organisational point of view, the following areas have been defined in the ICTS Map:

- Astronomy and Astrophysics
- Ocean, Life and Earth Sciences
- Health Sciences and Biotechnology
- Information and Communication Technology
- Energy
- Engineering
- Materials
- Social Sciences and Humanities

That is how it was presented in the previous edition of the ICTS Map book published in 2015 and how the ICTS list approved by CAIS is organised. As a novelty, the current edition includes specific examples of the research results obtained by means of the use of these infrastructures in order to demonstrate the importance of having them available in Spain. It pretends to show the wide range of applications and services that is available in the ICTS. The daily studies conducted in these infrastructures continually generate results at the forefront of the knowledge

of all the scientific disciplines, which could not have been obtained or would have taken more time, investment and effort to achieve without these infrastructures.

In light of this document, the reader is invited to learn about the current ICTS Map with the guarantee that they will discover unknown scientific applications that will contribute to improving our scientific culture. You are also invited to expand this knowledge by accessing the online resources featuring each of the ICTS (websites, social networks, etc.), which are indicated in their descriptions. These will provide more extensive information about the technical characteristics of the facilities, their applications and their access procedures. The numbers in parentheses that can be found in some of the text refer to the list of references at the end of this book, for all of you who wish to deepen scientific knowledge. Finally, everyone is invited to visit these scientific infrastructures, which are unique in Spain because of their size, situation and/or content.

**General Secretariat of Scientific Policy Coordination.**  
**Deputy General Directorate for Large Scientific and Technical Infrastructures**







@RBD\_DOÑANA

**ICTS WITH A SINGLE LOCATION**





## NATIONAL ACCELERATOR CENTRE (CNA)

www.cna.us.es



The Spanish National Accelerator Centre (CNA) was founded in 1998, making it the first Spanish research centre with particle accelerators. It is located at the Science and Technology Park at the Isla de la Cartuja in Sevilla. It is a jointly-operated centre between the University of Sevilla, the regional government of Andalusia and the Spanish National Research Council (CSIC), where multi-disciplinary research with accelerators is conducted.

It provides the national and international science community with six different facilities for this purpose. It has four different accelerators: a Van de Graaff 3 MV Tandem accelerator for the application of analysis techniques with an associated measurement service for the application of IBA techniques (Ion Beam Analysis); a Tandem Cockcroft-Walton 1 MV Tandem accelerator for the application of the Accelerator Mass Spectrometry technique (AMS); a new dating system called MiCaDaS (Mini Carbon Dating System), which reduces, lowers the cost of and simplifies the  $^{14}\text{C}$  dating analysis, a unique service in Spain; and a cyclotron which provides protons of up to 18 MeV with two different uses: material irradiation and radioisotope production. It has also a PET/CT scanner for humans that enables short half-life radiopharmaceutical studies to be conducted, which cannot be conducted in any other way, and has a  $^{60}\text{Co}$  irradiator which is currently the most

intense of its kind in Spain and one of the most versatile available today.

With all of the equipment mentioned above, the CNA can conduct research across a very extensive range of application, covering disciplines such as biomedicine, material sciences, pharmacology, environmental sciences and nuclear physics and instrumentation. As a recent example, using the Accelerator Mass Spectrometry (AMS) technique, the  $^{236}\text{U}$ ,  $^{237}\text{Np}$  and  $^{239,240}\text{Pu}$  radionuclides have been detected and measured in a column of sea water and in a sample of sediment from the Ligurian Sea, between Nice and Corsica (West Mediterranean). These radionuclides from the family of actinides are essentially produced by human, anthropogenic activities, and their presence in the environment is generally due to civil and military uses of nuclear energy. The novelty of this work is a new methodology that has been developed to address the

measurement of these nuclides in very small samples, with a sensitivity of tens of thousands of atoms, which is unattainable with other analysis techniques. Furthermore, these radionuclides have been measured in sea water and sediment from the same station for the first time, allowing to obtain unique information about the bio-geochemical cycles involved in its distribution in the Mediterranean Sea. In Spain, only the CNA has accelerators, the sample preparation procedures and the specialised staff to achieve this extremely high sensitivity (an atom of the actinide elements, between  $10^{20}$  atoms of other types), and there are very few centers internationally with this capacity(1).







## CENTRO NACIONAL DE INVESTIGACIÓN SOBRE LA EVOLUCIÓN HUMANA (CENIEH)

www.cenieh.es



The Centro Nacional de Investigación sobre la Evolución Humana (CENIEH) was founded in 2004 as a public consortium co-financed in equal parts by the Central Government and the Regional Government of Castilla y León. Since 2009, it has been located in one of the buildings that makes up the Human Evolution Complex in the city of Burgos. The CENIEH conducts research in the field of human evolution during the Pliocene and Pleistocene periods, promoting awareness and the transfer of knowledge to society while driving and supporting excavations of sites from these periods, both in Spain and in other parts of the world. The CENIEH is also responsible for preserving, restoring, managing and recording palaeontological and archaeological collections from excavations in Atapuerca and other Spanish and international sites. It is currently based on three research programmes: Archaeology, Geochronology, and Geology and Palaeobiology.

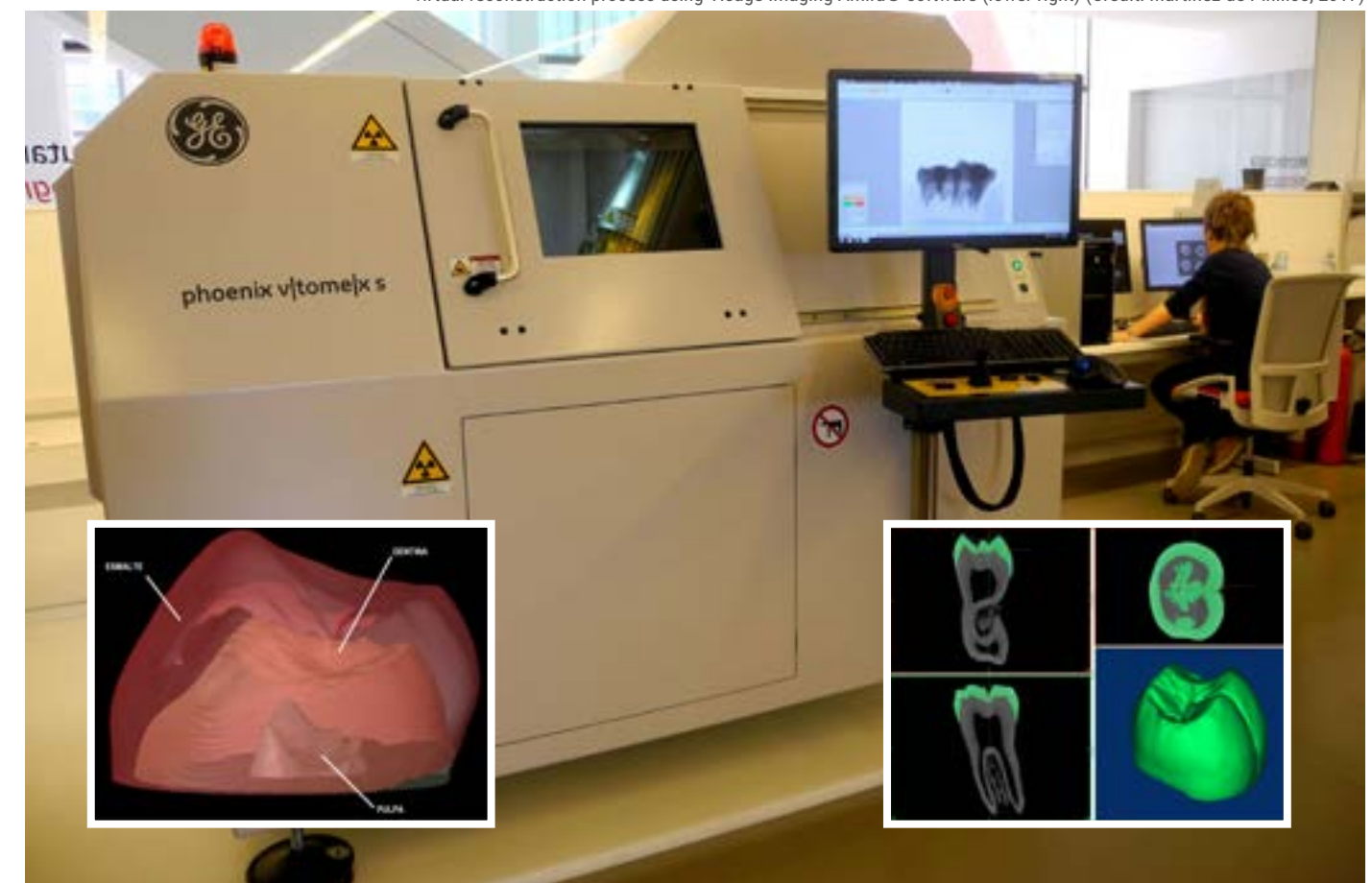
Since it was set up, there have been many studies using the facilities of this ICTS, which have produced results that helped uncover significant matters regarding human evolution. In that respect, the Palaeomagnetism and Electron Spin Resonance (ESR) methods at the CENIEH for dating the tools and bones from sites in Ain Boucherit (Algeria) have proven essential for changing our conception and knowledge of the emergence of human culture and the evolution of the first *Homo* on the African continent. The study of these discoveries has had a global impact on the knowledge of the first stages of human evolution in Africa and the world. Before this discovery, very little was known about the first occupations of the hominids and their activities in the north of Africa. These results have demonstrated that the first hominids made lithic tools in Northern Africa 2.4 million years ago, meaning they are almost contemporary compared to the first

lithic utensils discovered in East Africa, which date back 2.6 million years (2).

Meanwhile, the application of micro-computed tomography in the field of dental anthropology reveals new variables with a high taxonomic and phylogenetic potential and which, in the case of the human teeth found at the Gran Dolina-TD6 site in the Atapuerca mountains, reveal a large number of primitive characteristics shared with the oldest members of the *Homo* genus, but there are also inherited features that appear in subsequent populations such as the Sima de los Huesos and the Neanderthals. This technique has enabled the virtual extraction of dental pieces that remained hidden within the maxilla and mandibular bones, meaning the external and internal morphology of the *Homo antecessor* teeth can be described in great detail using non-invasive methods with virtual

histological sections and high-definition three-dimensional reconstructions. The interpretation of these results suggests a less linear colonisation of the European continent, where *Homo antecessor* could have represented one of the subsequent migratory waves that entered Europe from Southeast Asia over one million years ago. This provides significant information about the origin of the European population and the possible relationships between groups (3).

Tomographic image of a molar crown (lower left) and the visualization of the different dental tissues after the segmentation and virtual reconstruction process using Visage Imaging Amira® software (lower right) (Credit: Martínez de Pinillos, 2017)







@Fernando de la Gándara

## INFRASTRUCTURE FOR AQUACULTURE OF ATLANTIC BLUEFIN TUNA (ICAR)

The Infrastructure for Aquaculture of Atlantic Bluefin Tuna (ICAR) is devoted to study aquaculture and developing techniques to breed bluefin tuna (*Thunnus thynnus*) in captivity. It is managed by the Spanish Institute of Oceanography (IEO) and consists of the Marine Aquaculture Plant and the Facility for Controlling the Reproduction of Atlantic Bluefin Tuna (ICRA), both in Mazarrón, Murcia.

www.icar.ieo.es



Sustainable growth can only be achieved through efficient production of high-quality, environmentally friendly fishing products. One of the European Union's objectives for 2030 is to double aquaculture production. Europe is well positioned to achieve this objective in terms of experience, technology and know-how in crucial areas for the progress of marine bio-economy. This is a significant challenge for the EU's scientific community in terms of remaining a global leader in aquaculture, transferring excellent research and contributing to the industrial growth and innovation in this area. Bluefin tuna is an iconic species that has fed Mediterranean populations for millennia.

In the 1990s, this very valuable species was overfished in its fishing grounds, almost leading to its collapse. In 2007, a recovery

plan for this species was implemented. It established limits for catching, minimum sizes and fishing periods. Therefore, to ensure the quantity and quality of the supply of bluefin tuna in an increasingly important and selective market, production must employ comprehensive aquacultural techniques (as with other species such as sea bream, sea bass and turbot). This will also help the natural populations to recover the structure they had hundreds of years ago more quickly. In the long term, potential sustainability of bluefin tuna is associated with advances in the domestication of this species.

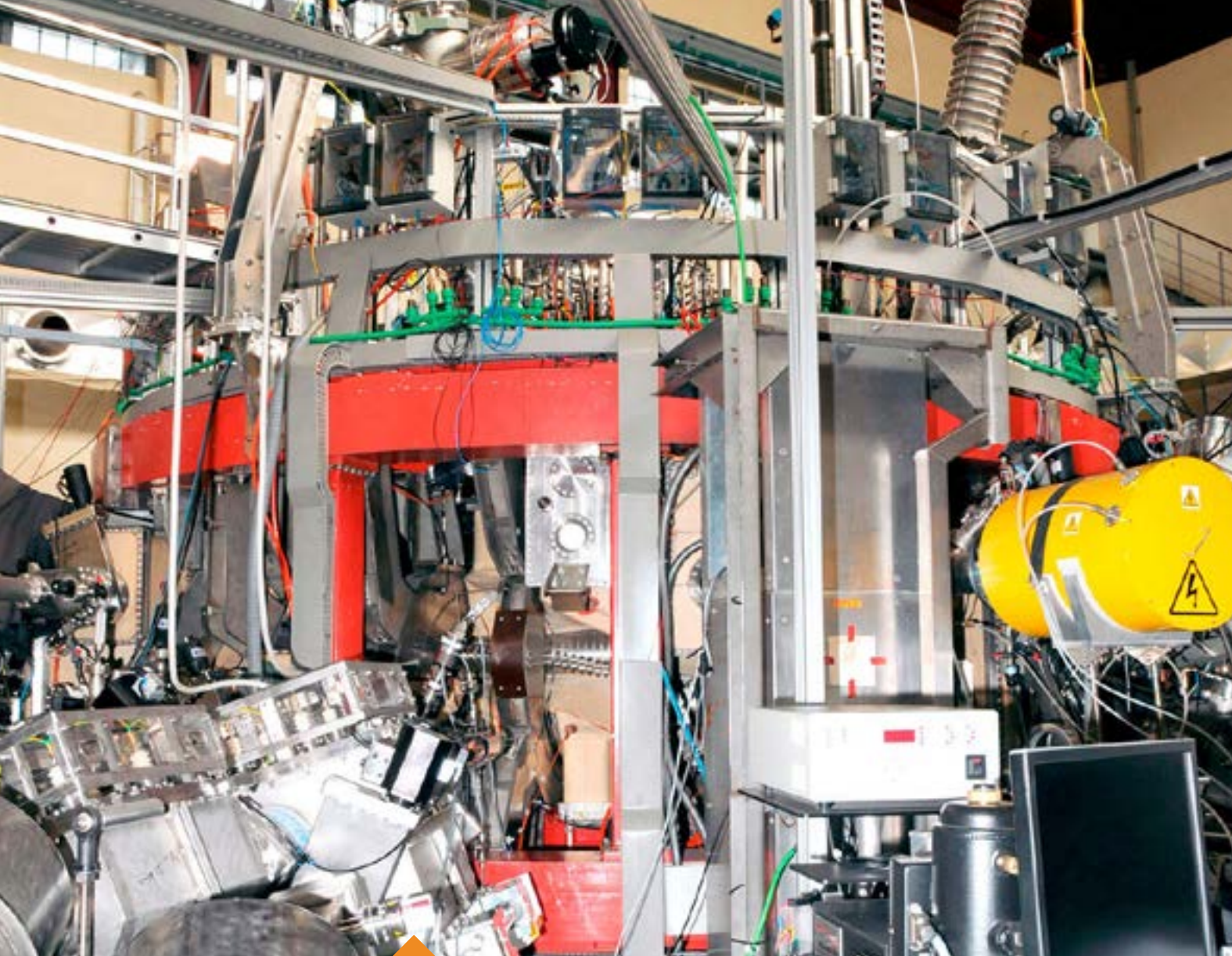
At the ICAR facilities, the only one in the world for this particular species, reproduction, incubation, larval rearing and weaning and pre-ongrowing studies can be conducted. These facilities also offer

the opportunity to conduct research in different fields of interest in aquaculture, such as behaviour, physiology and stress, wellbeing, pathology, nutrition and molecular biology. This is all necessary for contributing to the sustainable production of Atlantic bluefin tuna through complete aquaculture techniques aside from fishing and to increase knowledge of their biology to better manage their fisheries, which contributes to sustainability.

Top left box: bluefin tuna eggs. Bottom left box: bluefin tuna larva at 18 days post hatching (dph) @Fernando de la Gándara







## NATIONAL FUSION LABORATORY (LNF)

[www-fusion.ciemat.es](http://www-fusion.ciemat.es)



The LNF is a department within the Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), a public research organisation belonging to the Spanish government. It is located in the CIEMAT headquarters in Madrid and its activity started in 1998 when the TJ-II experiment began. The LNF is the central point for magnetic confinement fusion research in Spain. It leads Spanish participation in the construction of the international ITER project (the first magnetic confinement fusion device that will produce net energy and test the technologies required to construct the first commercial reactor to produce electricity) and it played a key role in ensuring the locating of the European F4E Agency in Spain. It has also represented Spain in the 'Broader Approach' agreement signed between the European Union and Japan since it began,

as well as in the projects included in the ESFRI roadmap and the European fusion programme.

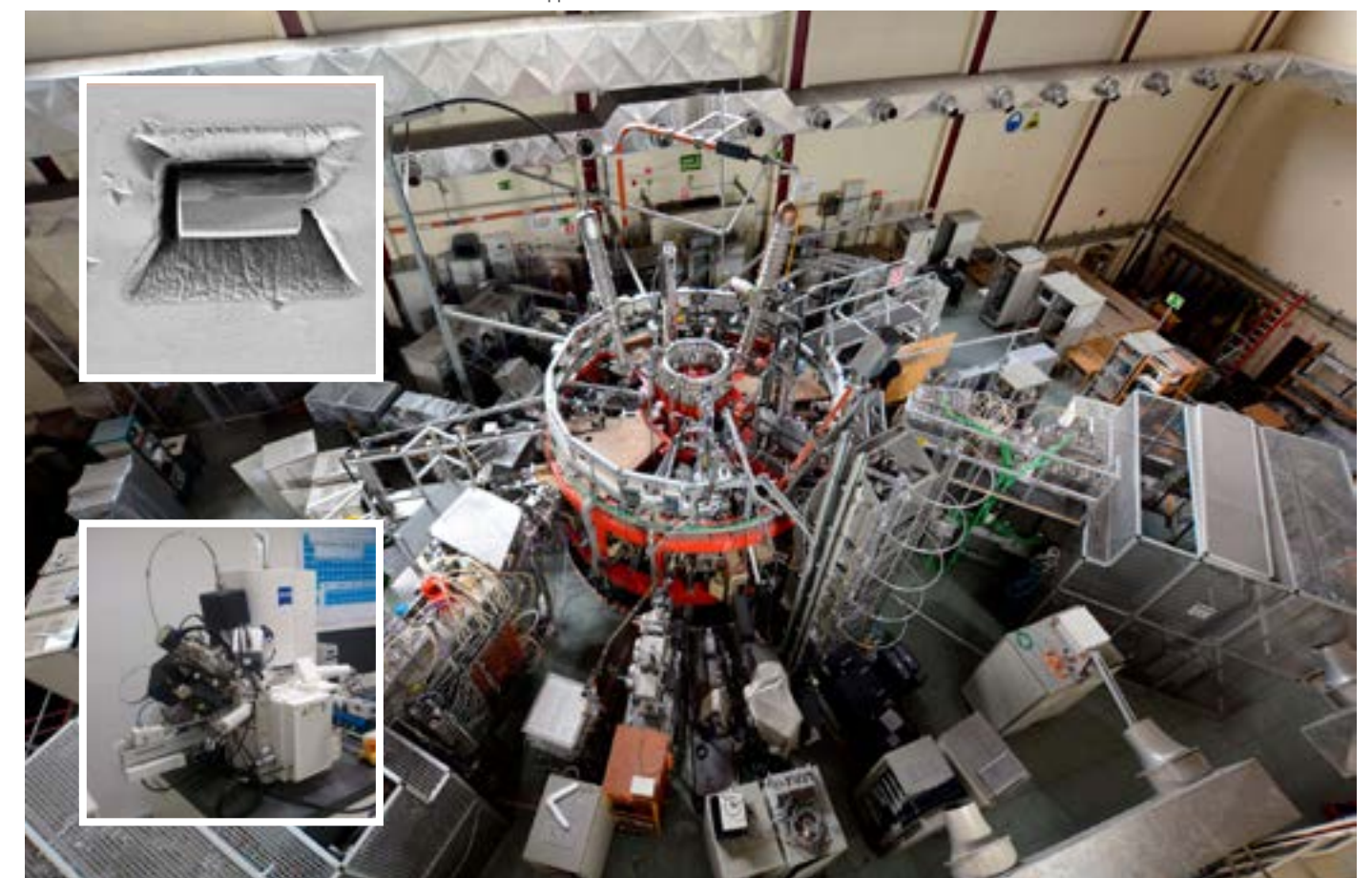
Research in magnetic confinement fusion is internationally based on two activity packages. On the one hand, the technologies required to construct and operate fusion reactors: materials, superconductors, tritium generation, energy extraction, remote maintenance, etc., and on the other hand, the study of plasmas confined at high temperatures. With regard to the former, the LNF has laboratory capabilities to distinguish and modify by radiation construction materials for these reactors. One of the principal advances from this Unique Scientific and Technical Infrastructures (ICTS) in this respect has been the attainment of lamellas of steels that are of particular interest for fusion through the focused ion beam (FIB) technique to analyse the

microstructure through the transmission electron microscopy (TEM) of the area irradiated with low-energy ions. The added benefit in contrast to classic methods is the ability to select the area of interest for the subsequent study of the microstructure. This is especially relevant in the case of irradiated materials as the irradiation volume, and in particular the depth of irradiation, is located at the micrometric scale.

In the future, the fusion of hydrogen isotopes will produce a safe energy source that is almost inexhaustible and is more environmentally friendly. Achieving this reaction on Earth requires keeping the fuel in a reactor at more than 150 million degrees centigrade, in a state known as "plasma". This means using intangible containers such as magnetic fields. Today, we know that the reactor must be 1000 m<sup>3</sup> or more for energy profitability. This

represents a significant technological challenge. Such a large volume is required, in part, because the turbulence of the plasma reduces the efficiency of the reactor. Within its second technology package, the LNF is home to the TJ-II stellarator, a medium-sized magnetic confinement device. TJ-II has been fundamental for conducting studies to control this turbulence, its results have led to a better understanding of the physics of this phenomenon, and is key to controlling the reactor's efficiency. This is all essential in order to attain reactors that better contain the fuel, whether they are smaller or cheaper.

Lower and upper left boxes: manufacture of TEM lamellae at micrometric scale of materials of interest for fusion.







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## CANFRANC UNDERGROUND LABORATORY (LSC)



[www.lsc-canfranc.es](http://www.lsc-canfranc.es)

It is the only underground facility in Spain and the second most eminent underground laboratory in Europe because of its size and characteristics. Since 1986, taking advantage of the location of the Canfranc railway tunnel in the Pyrenees in Huesca, experiments have been carried out here in dark matter searches and the nature and properties of neutrinos. The ICTS is located at a depth of 800 m below the Pyrenees mountain of ElTobazo, between the railway tunnels and the motorway tunnel of Somport. This depth eliminates most of the cosmic radiation present on the surface and allows for experiments that, due to their high level of sensitivity, require a low radiation background. The ICTS became fully operational in 2010 and carries out material screening services by measuring radioactivity for scientific and technological-industrial applications, as well as geophysics and underground biology studies.



With regard to particle physics, the NEXT project stands out. It is being carried out in the LSC facilities. The project is a global leader that studies the nature of neutrinos, searching for an unusual type of decay called neutrino-less double beta decay. If observed, it would mean that the neutrino is its own antiparticle, that there is a new mechanism for giving mass to elementary particles, other than the Higgs mechanism, and that it provides a basis for explaining why the Universe contains an excess of matter over antimatter. The process that it aims to discover is very unlikely, with a half-life of around  $10^{27}$  years,

which requires a detector containing between 100 kilograms and 1 ton of active material. There is currently no experiment capable of reaching these masses with the energy resolution and background contamination required to detect it.

The LSC facilities reduce the radioactive background contamination in a controlled environment with airborne radon, and the detector is also protected from exterior gamma radiation by a lead castle shield and from cosmic muons by the mountains surrounding the laboratory. Currently, the NEXT-NEW detector is measuring the

double beta decay of  $^{136}\text{Xe}$ , which is essential for demonstrating the final potential of this new technique. The experiment is able to both measure the energy emitted in the decay and reconstruct the trajectory of the generated electrons. This is essential for distinguishing the signal from the background contamination generated by the radioactive impurities present in the construction materials and in the setting surrounding the experiment(4).







@RBD\_DOÑANA

## DOÑANA BIOLOGICAL RESERVE (RBD)

[www.ebd.csic.es/icts-donana](http://www.ebd.csic.es/icts-donana)



The Doñana Biological Reserve (RBD), located in the southwest of the Iberian Peninsula was founded in 1964 by the Spanish National Research Council (CSIC). The reserve is managed by the Doñana Biological Station (EBD), a research institute belonging to CSIC. The protected area of Doñana, also known as the Doñana Natural Area (END), extends over 128,737.7 hectares and includes the National Park, special protection areas and the Natural Park of Doñana. In both areas there is a regulated use of natural resources (mainly forestry, fishing, and livestock). The Biological Reserve forms part of the National Park and is composed of two protected areas: the 6,794 hectares of the Doñana Biological Reserve, and the 3,214 hectares of the Guadamar Biological Reserve.

The National Park of Doñana was declared Biosphere Reserve by UNESCO in 1980, Wetland of International Importance by RAMSAR in 1982, a Special Protection Area for birds (Natura 2000 network) in 1987, a World Heritage Site in 1994, and a Site of Community Importance (Natura 2000 network) in 1997. This protected area, which includes four large ecosystems (beach, dunes, Mediterranean scrubland, and marshland) hosts to numerous endemic and endangered species. As many as 700,000 water birds gather in the marshland each winter, making Doñana one of the most important wetland areas in Spain and Europe.

Doñana has one of the most extensive records of long-term ecological monitoring data of all the protected natural areas across Europe. Through the monitoring programme, the ICTS-RBD provides a

database of physical and biological data obtained from the ecosystems which have been systematically and continuously recorded over the last 30 years. The programme includes the ecological monitoring of landscape, fauna, limnology, aquatic macroinvertebrates, butterflies, flora and vegetation, etc. as well as the human dimension of socio-ecological estimates to analyse the drivers of change in ecosystems and in the services they provide. It is important to highlight the automated monitoring of different physiological variables of the juniper tree (*Juniperus phoenicea* subsp. *Turbinata*), both individually and as a community. All this has been made possible thanks to the installation of a network of sensors fuelled by photovoltaic panels that can be accessed online through the ICTS-RBD website. The selected juniper tree specimens were monitored with sap flow sensors, dendrometers on the branches,

humidity and temperature sensors on leaves and at different depths in the ground, measuring how this community contributes to CO<sub>2</sub> fixation.

The long term monitoring of biodiversity an ecology at Doñana is part of the international network (ILTER, International Long Term Ecological Research network), and presents an unprecedented opportunity to provide the scientific community with access to consistent time series of data that are collected with international harmonised methodological protocols. The monitoring was initially focussed on birds but, over time, a larger diversity of parameters has been incorporated. All this information provides a solid basis to the management of this protected area, understanding it, predicting emergency situations, obtaining tools to reduce the effects of global change, etc. (5).



@RBD\_DOÑANA





@Sergio Ruiz

## ALBA SYNCHROTRON

The ALBA Synchrotron is a complex of electron accelerators aimed at producing synchrotron light to visualise the structure and properties of matter, especially on at the nanoscale. It is located in Cerdanyola del Vallès (Barcelona) in the Parc de l'ALBA. It is a public consortium, equally co-financed by the Central government and the regional government of Catalonia. Construction started in 2006, it was opened in 2010 and has operated with official users since mid-2012.



[www.albasynchrotron.es](http://www.albasynchrotron.es)

ALBA is a third generation synchrotron light source, similar to the latest sources built in Europe. The complex of accelerators is composed of a lineal accelerator used to accelerate electrons up to 100 MeV, a booster, where the electrons are accelerated up to 3 GeV, and a storage ring, where the synchrotron light is generated and emitted to the different experimental stations. Every year, the ALBA Synchrotron produces about 6,000 hours of beam time and hosts more than 2,000 researchers, from both the education and industrial sector. ALBA currently has eight operational beamlines, which are mainly focused on biosciences, magnetism and material sciences. There are four more beamlines in the design or construction phase which will be in operation from 2020.

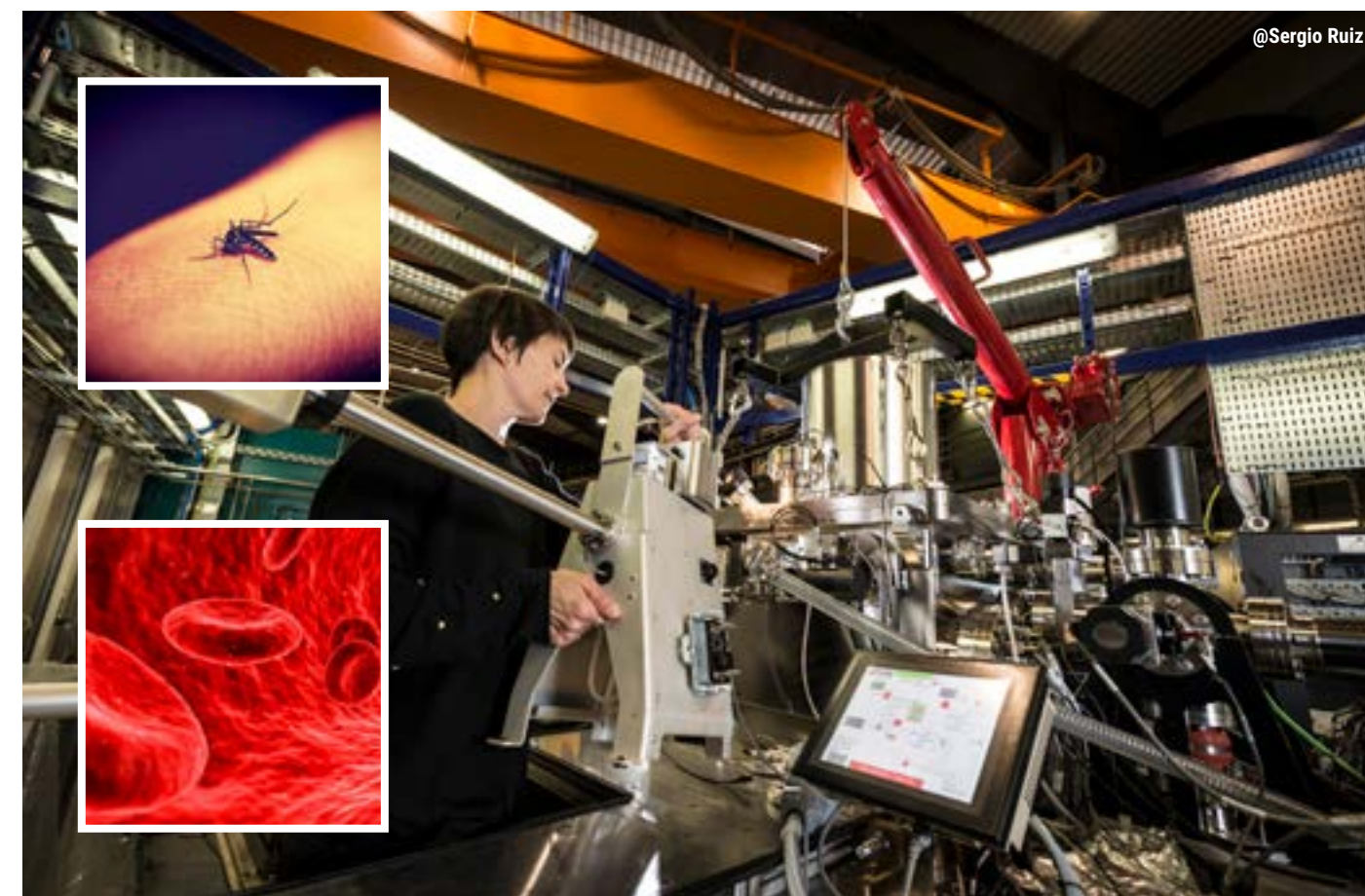
Since opening, the ALBA Synchrotron has contributed to uncovering scientific

matters in a wide range of disciplines: how to manufacture more resistant cement, control the magnetic properties of advanced materials or test the effectiveness of new methods for decreasing contaminants. With regard to biomedicine, it is worth highlighting that, thanks to the synchrotron light, it has been able to reveal previously unknown details about how the malaria parasite behaves.

Malaria is transmitted through infected mosquito bites, which leads to the parasite entering the blood and the resulting infection of the victim's red blood cells. Once inside, the parasite uses haemoglobin, which is in the red blood cells, as a nutrient in turn creating waste that is toxic for the parasite, but it manages to avoid this by grouping it into crystals. For the first time, this crystallisation rate has been measured and a new model to explain how it functions has been proposed with help from the ALBA Synchrotron (6). This ac-

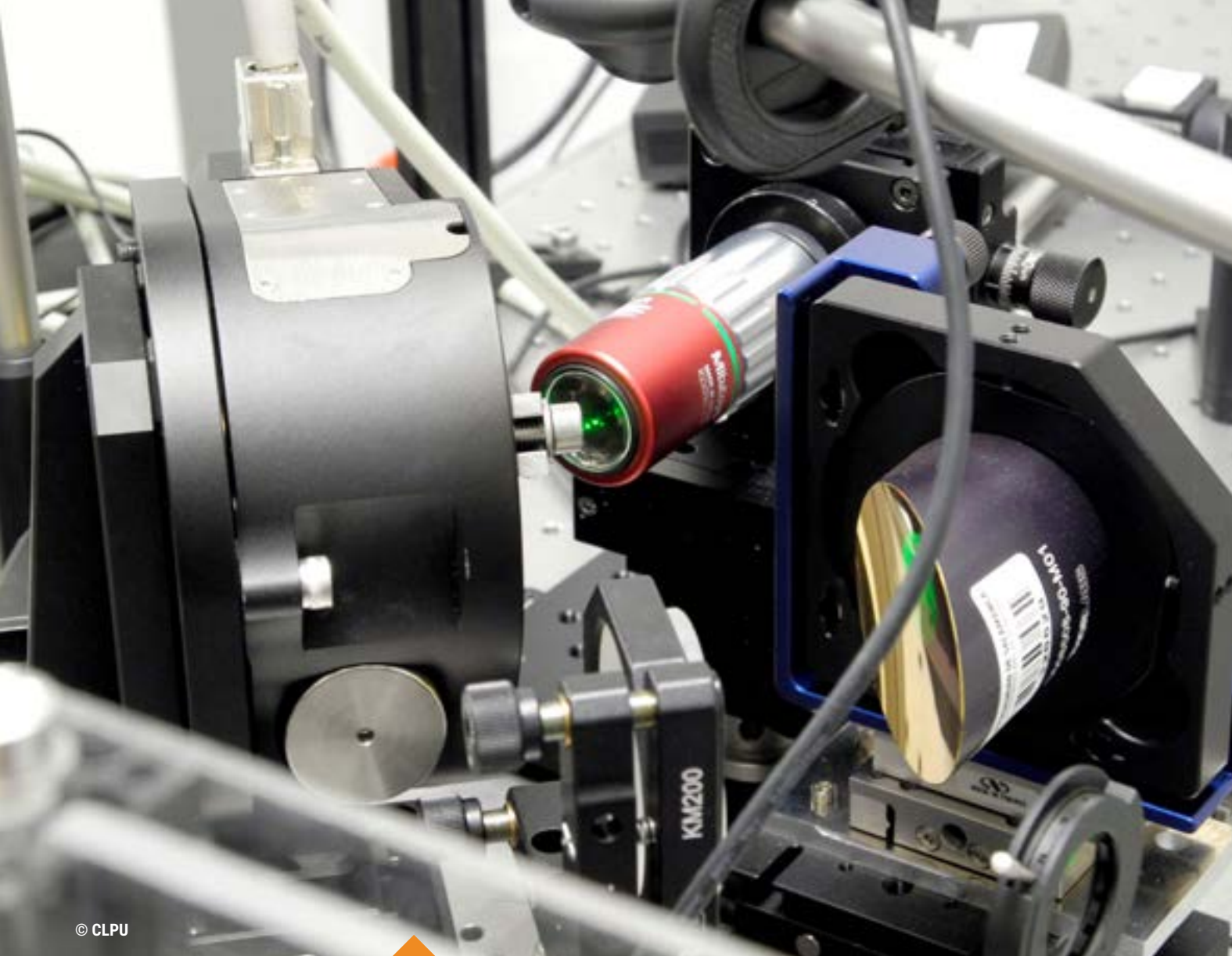
complishment was possible thanks to the combination of two modern microscopy techniques: fluorescent X-rays and X-ray tomography. The latter was performed in the ALBA Synchrotron and is only available in three synchrotrons in the world.

Malaria kills over 400,000 people every year. The current resistance to continued use of certain anti-malaria drugs clearly shows the need for new, effective medication. The knowledge produced by using the ALBA Synchrotron will facilitate the development of new drugs that will slow down the disease by attacking the mechanism the parasite uses to avoid the obstacle which could limit the rate at which it spreads.



@Sergio Ruiz





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## CENTRE FOR ULTRASHORT ULTRA-INTENSE PULSED LASERS (CLPU)

The Spanish Pulsed Lasers Centre (CLPU) is an infrastructure focused on researching and developing ultra-intense pulsed laser technology. It is located at the Science Park of the University of Salamanca (Villamayor Campus), managed by a public consortium founded in 2007 and co-financed by the Spanish government, the regional government of Castile and León, and the University of Salamanca.

www.clpu.es



This facility hosts VEGA, a titanium-sapphire laser system with Chirped Pulse Amplification (CPA) technology that is able to work with a pulse duration of 30 femtoseconds and reach a peak power of one petawatt. The structure of VEGA is internationally unique and is composed of three perfectly-synchronised phases due to the fact that they share the same pulse generator system: VEGA1 and VEGA2 (20 and 200 terawatts respectively, both at 10 shots per second), and VEGA 3 (1 petawatt at 1 shot per second). The three systems are operational: the first two are the most powerful lasers in Spain and VEGA3 is one of the 10 most powerful lasers in the world. Furthermore, the facility has other CPA lasers with a higher repetition rate and a laser with a duration of only six femtoseconds when stabilised in operation.

Thanks to such a versatile laser system design, there is an extensive list of poten-

tial applications, including the pioneering scientific disciplines. Among other applications, it is important to note the measurement and control of the elementary nature processes at attosecond time scales; the development of new light sources; the production of nanoparticles and nanosurfaces; the micromachining of all material types for industry; the development of microsurgery techniques; the display of molecules and biological tissues; electron and ion acceleration; X-Ray generation and new applications in plasma physics, nuclear physics (such as laser protontherapy) and particle physics (quantum vacuum).

Obtaining neutrons is currently one of the most interesting fields for the national and international community. Their generation, analysis and multiple applications are rising fields in this research area because, in contrast to photons, the harder the material, the greater the neutrons' pen-

etration capability. Although different methods have been developed, most of them require large and extremely expensive nuclear infrastructures. The neutron sources generated by lasers, however, provide a viable and more efficient (directionality is achieved by using a neutron beam), more adaptable and cheaper alternative. The unique characteristics of the VEGA petawatt laser system have allowed a high number of neutrons to be obtained, which is enough for a beam composed of these particles to be able to generate high resolution radiographies. This new method will be key for studying the state of some materials such as concrete and will therefore provide greater control of the real state of infrastructure with a large social impact.



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@Enrique Vidal Vijande/SOCIB

## COASTAL OBSERVATION SYSTEM OF THE BALEARIC ISLANDS (SOCIB)

www.socib.es



The Coastal Observation System of the Balearic Islands (SOCIB) is managed by the SOCIB consortium and is equally co-financed by the Spanish government and the regional government of the Balearic Islands. SOCIB has been operational since 2013 and is located in Palma de Mallorca. The activities carried out by SOCIB are mainly focused on the Western Mediterranean, especially the Balearic Islands and surrounding areas (the Alboran Sea, Algerian Basin, etc.). Thanks to its strategic location, near the area of transition between the Mediterranean and the Atlantic, it is one of the “hot spots” of global biodiversity. This means the SOCIB infrastructure is capable of meeting society's needs, scientific priorities, technological development, thus closing the innovation process cycle.

SOCIB's mission is to develop understanding of the Mediterranean within the global context of ocean research on three essential themes: climate, ocean health and real-time services. It promotes a paradigm change in observing the oceans, which was previously based exclusively on large ships but is now based on integrated, multi-platform systems. As a result it contributes to meeting the needs of a wide range of society's scientific, technological and strategic priorities. An example of this is the IBISAR service. This development was possible thanks to SOCIB's experience in coastal operational oceanography. It provides an open system in real time of meteo-oceanographic data obtained from a complex network of observation platforms (such as observations of surface current from drifters and

high-frequency coastal radars; forecasting services (such as currents predictions); the data management and distribution computer system (interoperable data and with quality controls following international standards); and its broad overview of transferring knowledge to society through the development of products and services, communication and science dissemination.

Emergency services and search and rescue operators require the most accurate data and forecasts to optimize search areas at sea and to respond, in the most efficient way, to maritime emergencies. In this frame, SOCIB is coordinating IBISAR, a service that is part of the Copernicus Marine Service. IBISAR provides the

most reliable real-time information about current forecasts in the Iberian-Biscay-Ireland (IBI) regional seas. Other public and private institutions also participate, the Spanish Maritime Safety and Rescue Agency (SASEMAR) collaborates as the main user of the service, and the Spanish Port System as the main actor in the IBI area of the Copernicus Marine Service.

IBISAR complements decision making support tools used by the main public and private agencies responsible for search and rescue operations, marine pollution control and maritime traffic control. In this respect, IBISAR helps to minimise response times to sea emergencies by optimising search area planning and allocating resources more effectively (7, 8).

Lower left box: Comparison of virtual trajectories (cyan dots) of particles advected with the velocity field from the regional model from the Iberian-Biscay-Irish regional seas (e.g. CMEMS-IBI MFC) against a real CODE drifter trajectory (red dots)







## OCEANIC PLATFORM OF THE CANARY ISLANDS (PLOCAN)

[www.plocan.eu](http://www.plocan.eu)



The Oceanic Platform of the Canary Islands is managed by the PLOCAN Consortium (equally co-financed by the Spanish government and the regional government of the Canary Islands). Its objective is to allow for research, technological development and pioneering innovation in the marine and maritime fields. The infrastructure permits the access to the ocean, and an efficient study of it with strict environmental guarantees, providing scientific laboratories, remote-control vehicles, test sites, and in general, technical tools and capacities located in the marine environment.

PLOCAN's main facility is an ocean platform located one and a half miles off the northeast coast of Gran Canaria, in the town of Telde, an area of 23 km<sup>2</sup> reserved for the scientific-technical experimentation of test sites. PLOCAN brings together the latest generation of advanced technological teams and highly qualified, specialised scientific-technical staff for long-term observation programmes, which is one of its main objectives.

In this regard, it is worth stressing its participation as manager and coordinator of the European Station for Time-series in the Ocean, Canary Islands (ESTOC). ESTOC is leading oceanic station from the eastern central Atlantic, and its objective is to contribute to international ocean observation programmes and strate-

gies such as JGOF, GOOS, OceanSITES, GMES, MSFD, GES, etc., sponsored by IOC/UNESCO, WMO and others. The continued and high-quality monitoring in a deep ocean observatory, such as ESTOC, contributes to an outstanding improving in the knowledge of the phenomena and processes characterising the ocean, whose impact directly affects at environmental, economic and social levels at regional and global scale. The contribution to the knowledge of the dynamics and biogeochemical processes ruling behaviour of the ocean in the Eastern Central region due to the studies generated at ESTOC, has enabled the identification and evaluation, at a regional level, of the main anthropogenic phenomena (global warming, acidification or deoxygenation, etc.). The international scientific commu-

nity has also been detecting these phenomena in other areas, and the global impact on seas and oceans is evident.

Two and a half decades of continued observation at one ocean site, with a remarkable quantitative and qualitative evolution of the measures, the involvement of over 30 national and international institutions and 50 scientists and experts, as well as resulting technological products and developments (some of them patented), has provided a strong position in the international arena as a leading oceanic node in the context of the global excellence programmes and initiatives concerning ocean studies and knowledge and its socioeconomic impact regarding climate change.







## PLATAFORMA SOLAR DE ALMERÍA (PSA)

www.psa.es



The Plataforma Solar de Almería is recognised as a Major European Science Facility. The International Energy Agency (IEA) began its construction in 1979, and in 1986 it became part of the Institute for Renewable Energies of Research Centre for Energy, Environment and Technology (CIEMAT), a Public Research Body administered by the State. It is located in the southeast of Spain, in the Tabernas Desert, at 37°05'27.8" north and 2°21'19" west.

The PSA is the largest research centre in Europe devoted to concentrating solar technologies, desalination and photochemistry. It receives over 1900 kWh/m<sup>2</sup> annual exposure to direct sunlight, making it a great location for developing, demonstrating and transferring concentrated solar technologies for applying to thermal, photo and thermochemical processes. It has the most advanced and

complete facilities in the world, along with sunlight and climate characteristics similar to those of many countries in the so-called "Sunbelt" (located between latitudes 40° north and 35° south), where solar technology development is very prominent.

The PSA offers a wide range of services, allowing for the study of multiple aspects of concentrating solar technology for thermal energy production, such as the optical and thermal characterisation of solar collectors, the characterisation of the materials that they are composed of, the qualification of new processes or testing, modelling, and simulation of thermosolar production plants. Its PTTL facility (Parabolic Trough Test Loop) is designed to be able to install and test solar thermal collectors with a large linear focus. It is the only experimental facility in the world in a public centre,

which means it can carry out the testing and certification of solar thermal collectors systems and its components employed in the construction of large solar collectors with a thermal fluid temperature of up to 400°C. The design and construction of the PTTL facility and the application of the new IEC 62862-3-2:2018 standard developed here, mean the industry can check if it meets the minimum requirements established in the guidelines to be able to sell them, and can compare results with other systems to identify which ones are best suited to the needs of the customer (9, 10, 11).

Further afield, the PSA is also developing technology that could provide solutions for some requirements on future missions to the Moon. One of the greatest challenges of these missions, apart from the space shuttles, is the provision of vital resources such as water, oxygen and fuel for

rockets and crews. Producing some of these resources on the Moon could significantly reduce the amount of material transported from the Earth. The main consumables are oxygen and nitrogen, and water for refuelling the life support systems. The PSA is working on setting the requirements for a plant that can produce oxygen from regolith (moon dust) using concentrated solar energy. As a testing facility it uses the SF-60 (12) Solar Furnace, which is one of the unique facilities of this ICTS, just like the PTTL facility.

Upper left box: red hot fluidized bed after solar test of lunar regolith reduction at the Solar Furnace of the Plataforma Solar de Almería







**NETWORK OF ICTS**



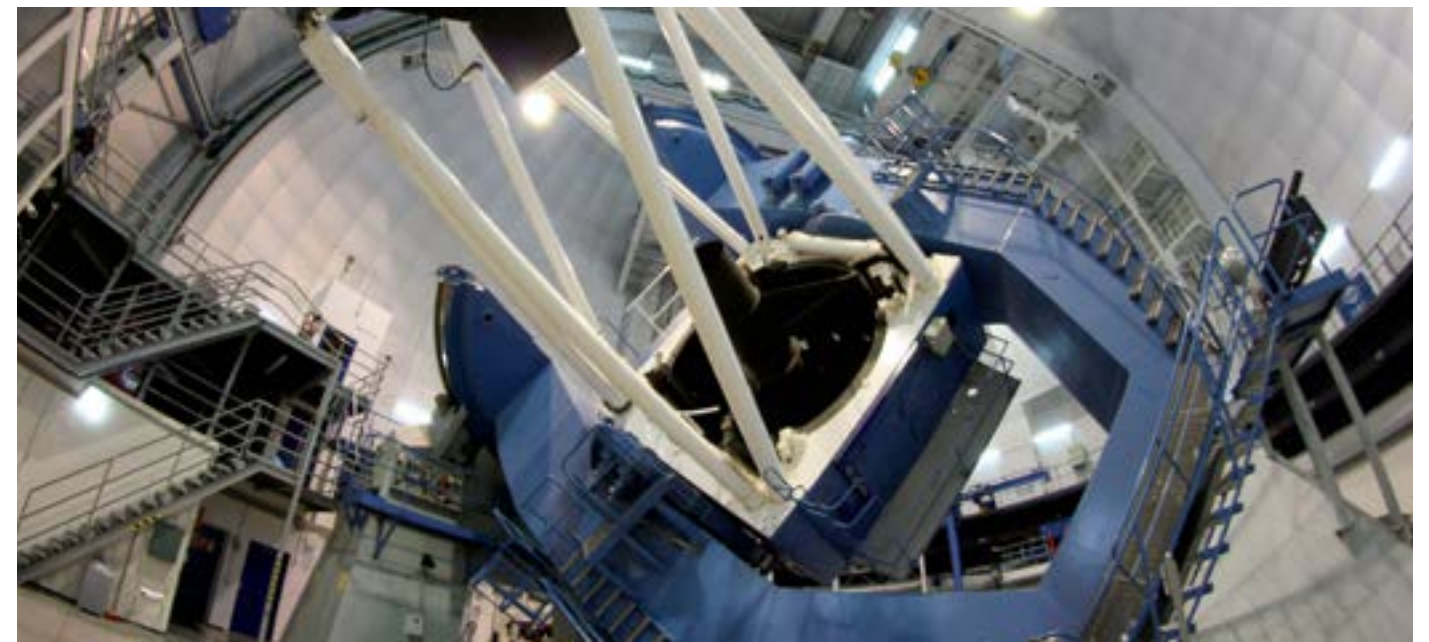


## ASTRONOMY INFRASTRUCTURES NETWORK (RIA)

[www.riastronomia.es](http://www.riastronomia.es)



- ◆ GRAN TELESCOPIO CANARIAS (GTC)
- ◆ OBSERVATORIOS DE CANARIAS (OCC)
- ◆ CALAR ALTO ASTRONOMICAL OBSERVATORY (CAHA)
- ◆ IRAM 30m TELESCOPE (IRAM 30m)
- ◆ YEBES OBSERVATORY
- ◆ JAVALAMBRE ASTROPHYSICAL OBSERVATORY (OAJ)



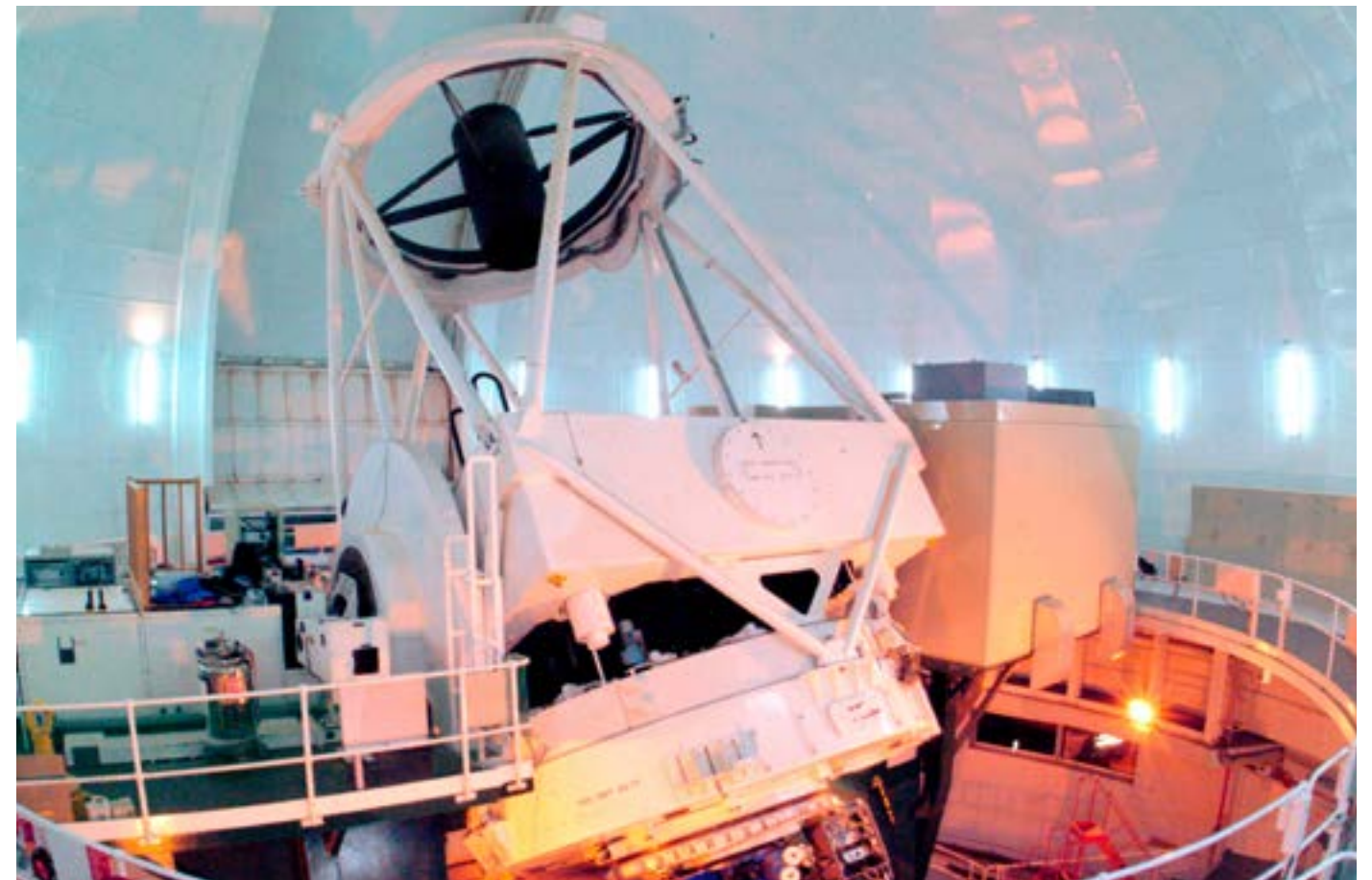
The Astronomy Infrastructures Network (RIA) was created in 2007 as a Work Group of the Spanish National Astronomy Commission (CNA) with the objective of advising the Central Administration and interested institutions in the field of astronomical infrastructure and instrumentation, and to create a forum for coordination between the different infrastructures in the network. Additionally, the RIA

coordinates studies related to future infrastructures and instrumental development projects, and systematically monitors the productivity of the different astronomical infrastructures.

The ICTS in the Astronomy Infrastructures Network are: Gran Telescopio CANARIAS, Observatorios de Canarias, Calar Alto Astronomical Observatory,

IRAM 30m Telescope, Yebes Observatory, and Javalambre Astrophysical Observatory.

The Network also ensures the coordination and optimisation of the Scientific Program of the European Space Agency (ESA) and the infrastructure of the European Southern Observatory (ESO).







ASTRONOMY  
INFRASTRUCTURES  
NETWORK (RIA)

## GRAN TELESCOPIO CANARIAS (GTC)

[www.gtc.iac.es](http://www.gtc.iac.es)



Gran Telescopio CANARIAS (GTC) with a main mirror 10.4 m in diameter, is currently the largest optical and infrared telescope in the world. It is located at the Roque de los Muchachos Observatory, in the town of Garafía, on the island of La Palma. The GTC, an initiative of the Instituto de Astrofísica de Canarias (Astrophysics Institute of the Canary Islands, IAC), is property of the public company Gran Telescopio de Canarias, S.A. (GRANTECAN) of the Spanish government and the Autonomous Community of the Canary Islands, which is responsible for its operation and development. It is supported by international collaboration from institutions in Mexico (the Astronomical Institute of the National Autonomous University of Mexico and the National Institute of Astrophysics, Optics, and Electronics) and the United States (University of Florida).

The GTC has been in operation since 2009 and its 36 hexagonal segments provide a light collection area equivalent to a circular monolithic mirror measuring 10.4 m in diameter. These segments act as a single surface thanks to the extremely precise optical alignment of these mirrors. Together with the accurate GTC pointing, tracking and guiding performance, it makes that the GTC image quality takes full advantage of the excellent characteristics of the sky above where the observatory is located.

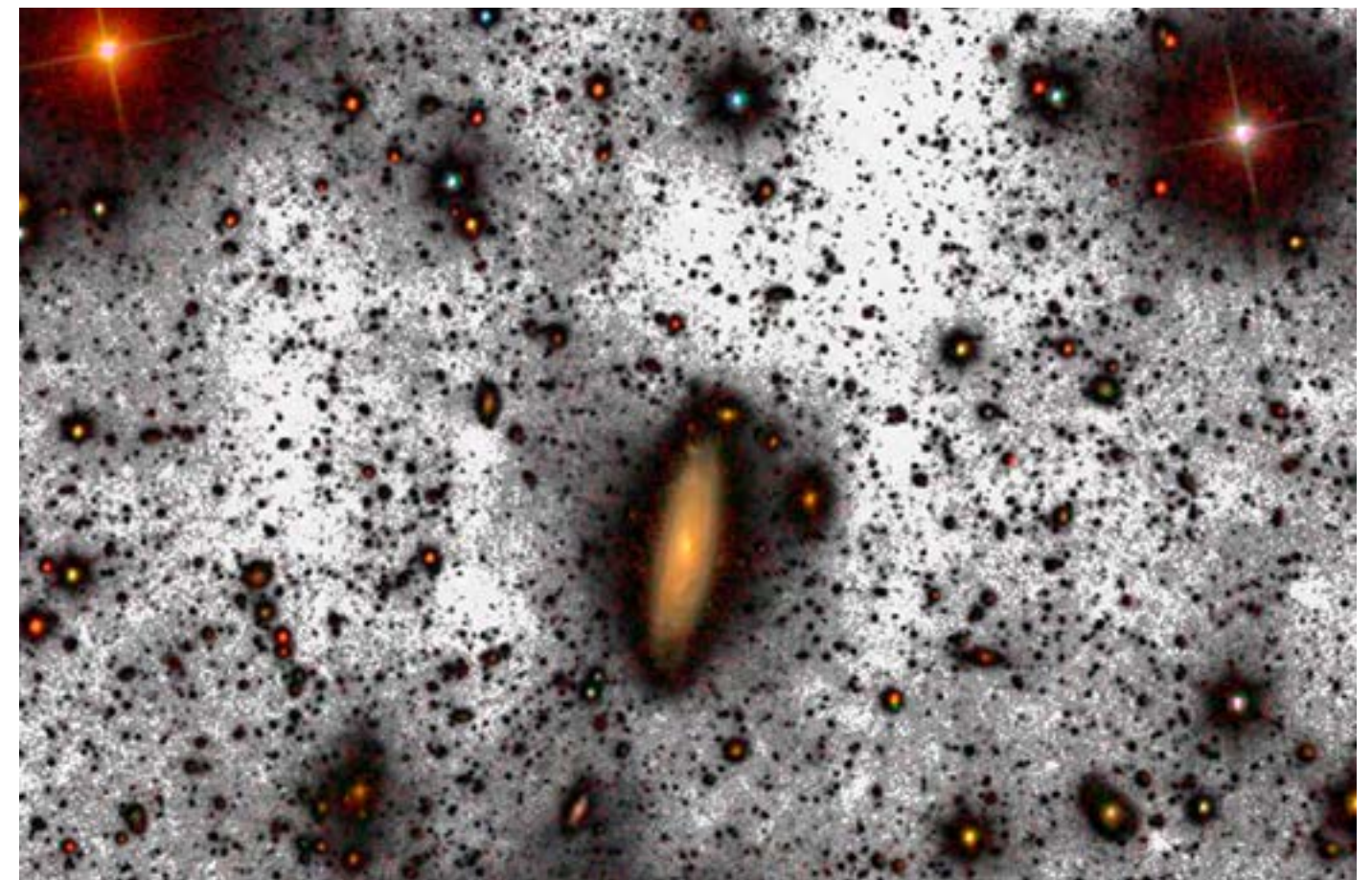
Until now, the GTC has led to significant progress in various fields of astrophysics, including the Solar System, exoplanets, stars and black holes, and galaxies of all

types. Among other results, the GTC has obtained the deepest images of galaxies ever taken from the Earth. An example of this is the image of galaxy UGC0180 and its surroundings, located 500 million light years from Earth (13). These detailed observations enable us to understand basic processes such as the formation and evolution of galaxies and the interaction between close galaxies and those in clusters. This information is essential for understanding how the universe has evolved from the Big Bang until now. To detect these very faint emissions, which are up to a billion times fainter than the human eye can see, telescopes with the largest light collection area are required. They need to be used in conjunction with highly

sensitive instruments and sophisticated observation strategies, something that only unique facilities like the GTC can do.

The unique, detailed observations like those provided by the GTC make the boundaries of the known Universe to continuously expand. This is because, owing to the nature of light, the farther into the universe we can observe, the further back we look in time, eventually meeting the first stages of the universe and therefore shedding light on questions about the origins of life, the Universe and “everything”. The phenomena studied in Astronomy also enable us to understand basic physical processes that will ultimately lead to the technology that we use in our daily lives.

Ultradeep image of galaxy UGC00180 showing its weak halo of four billion stars. Credit: IAC/GranteCAN







ASTRONOMY  
INFRASTRUCTURES  
NETWORK (RIA)

## OBSERVATORIOS DE CANARIAS (OCC)

www.iac.es



The Astronomical Observatories of the Canary Islands, which are run by the Instituto de Astrofísica de Canarias (IAC), consist of the Roque de los Muchachos Observatory (ORM) in La Palma, and the Teide Observatory in Tenerife (OT), both at an altitude of 2,400 m. The excellent astronomical quality of the sky above the Canary Islands, which is protected by law, makes them an astronomy reserve, which has been made available to the international scientific community since 1979. The OCC currently host telescopes and instruments belonging to 75 institutions from 25 different countries, forming the most important group of nocturnal and solar, visible and infrared astrophysical facilities in the European Union (EU), as well as the largest collection of multinational telescopes in the world.

With the contribution of one of these telescopes, the Galileo National Telescope (TNG), a new exoplanet, GJ 625 b, has recently been discovered close to our solar system, and is also considered to be one of the few that could be habitable. It has a mass approximately 2.8 times that of Earth's, has an orbital period around its star of about 14.6 days and is 21 light years from the Sun (14).

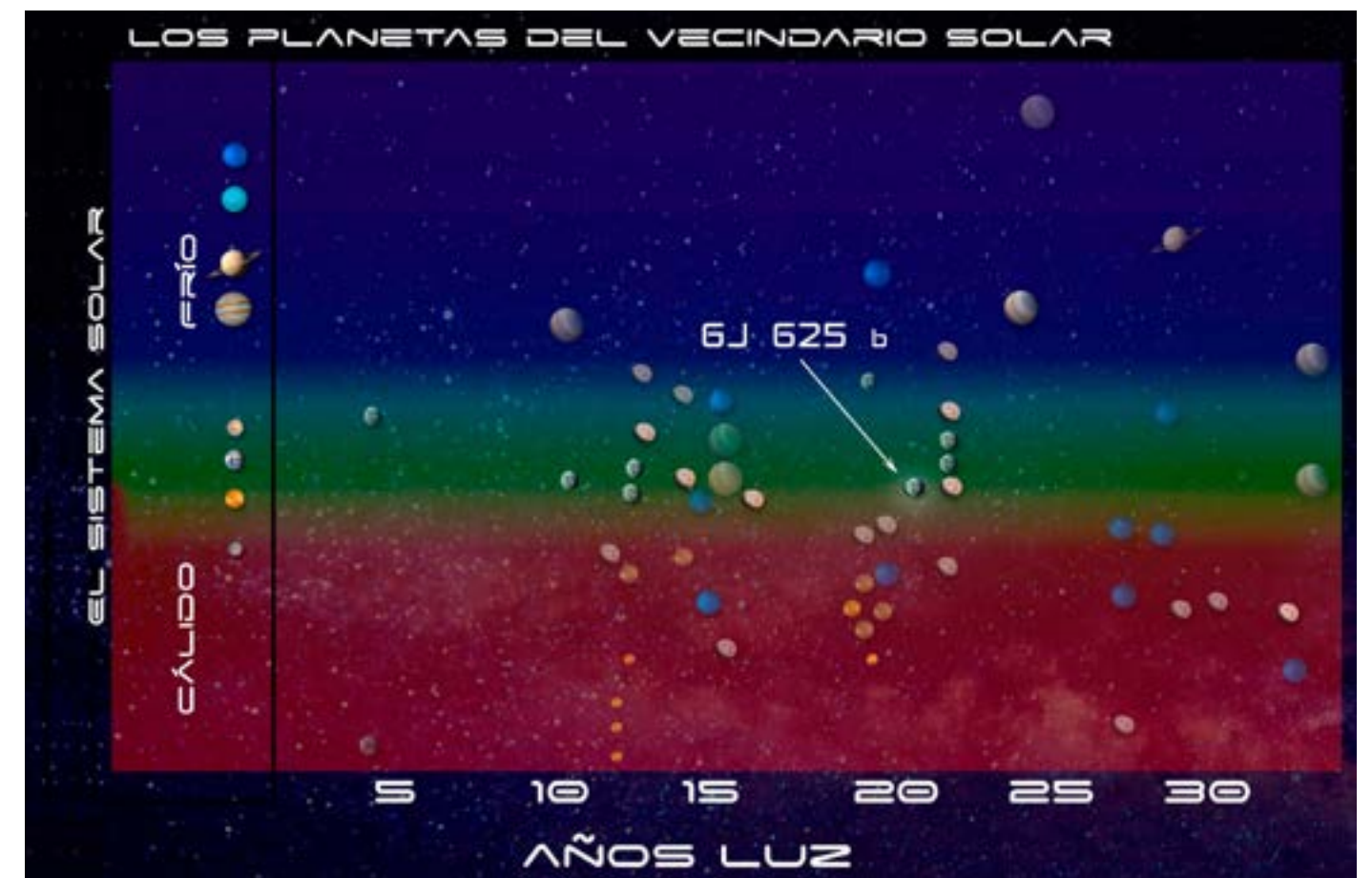
The discovery of a new exoplanet in the solar neighbourhood is also a significant step towards understanding the structure of the planetary systems around us and their formation process. This discovery required an optimised, ultra-stable spectrograph in order to measure radial velocity. The only instrument in the northern hemisphere that can reach the required level of precision is

HARPS-N, which is located in the TNG. Due to the star's position in the sky and the required precision, this discovery could not have been made at any other facility in the world.

Meanwhile, thanks to observations carried out at the William Herschel Telescope (WHT) with ACAM, and the Gran Telescopio Canarias (GTC) with OSIRIS, one of the brightest distant galaxies in the universe has been discovered: BG1429+1202, at a 2.82 redshift (when the universe was approximately 2.3 billion years old). The distant and very luminous BG1429+1202 galaxy was discovered through the analysis of one and a half million spectra of galaxies conducted by the Baryon Oscillation Spectroscopic Survey (BOSS) project, part of the Sloan Digital Sky Survey III. The

monitoring observations from the WHT telescope were the first to confirm that the quadruple image of BG1429+1202 was due to the effect of gravitational lensing of an elliptical galaxy, which acts as a gigantic natural lens (15). The ACAM instrument (Auxiliary-port CAMera) is one of the most efficient in medium-sizes such as the WHT and it obtains low resolution images and spectra within visible range. Access to one of the best telescopes in the world such as the WHT provided observation time for more detailed studies of BG1429+1202 with another ICTS, the Gran Telescopio Canarias. Both of these telescopes are located in the Roque de los Muchachos Observatory on the island of La Palma.

Known exoplanets in the solar neighborhood (up to ~ 35 light years), including the position of GJ 625. The green horizontal region marks the habitability zone. The solar system planets are spotted on the left for comparison







ASTRONOMY  
INFRASTRUCTURES  
NETWORK (RIA)

## CALAR ALTO ASTRONOMICAL OBSERVATORY (CAHA)

The Astronomical Observatory of Centro Astronómico Hispano en Andalucía de Calar Alto (CAHA) is located at an altitude of 2,168 metres in the Sierra de Los Filabres, Almería. It has been run by the Spanish National Research Council (CSIC) and the regional government of Andalusia since 2019, and is operated by the Instituto de Astrofísica de Andalucía (Astrophysics Institute of Andalusia).

The Calar Alto Astronomical Centre is the most important observatory with optical telescopes in continental Europe. Its main instruments are three telescopes with apertures of 1.23, 2.2 and 3.5 metres. It also has a fireball detection system that covers the whole sky visible from the observatory. The telescopes provide a wide variety of astronomical instrumentation in the optical

and near-infrared range, as well as direct image sensor cameras and low-, high- or very-high-resolution spectrographs. The observatory also has night-sky quality monitors, cleanrooms, electronic, mechanic and computer workshops, and vacuum chambers for aluminising large mirrors (up to 4 m), which provide aluminising services to the scientific community.

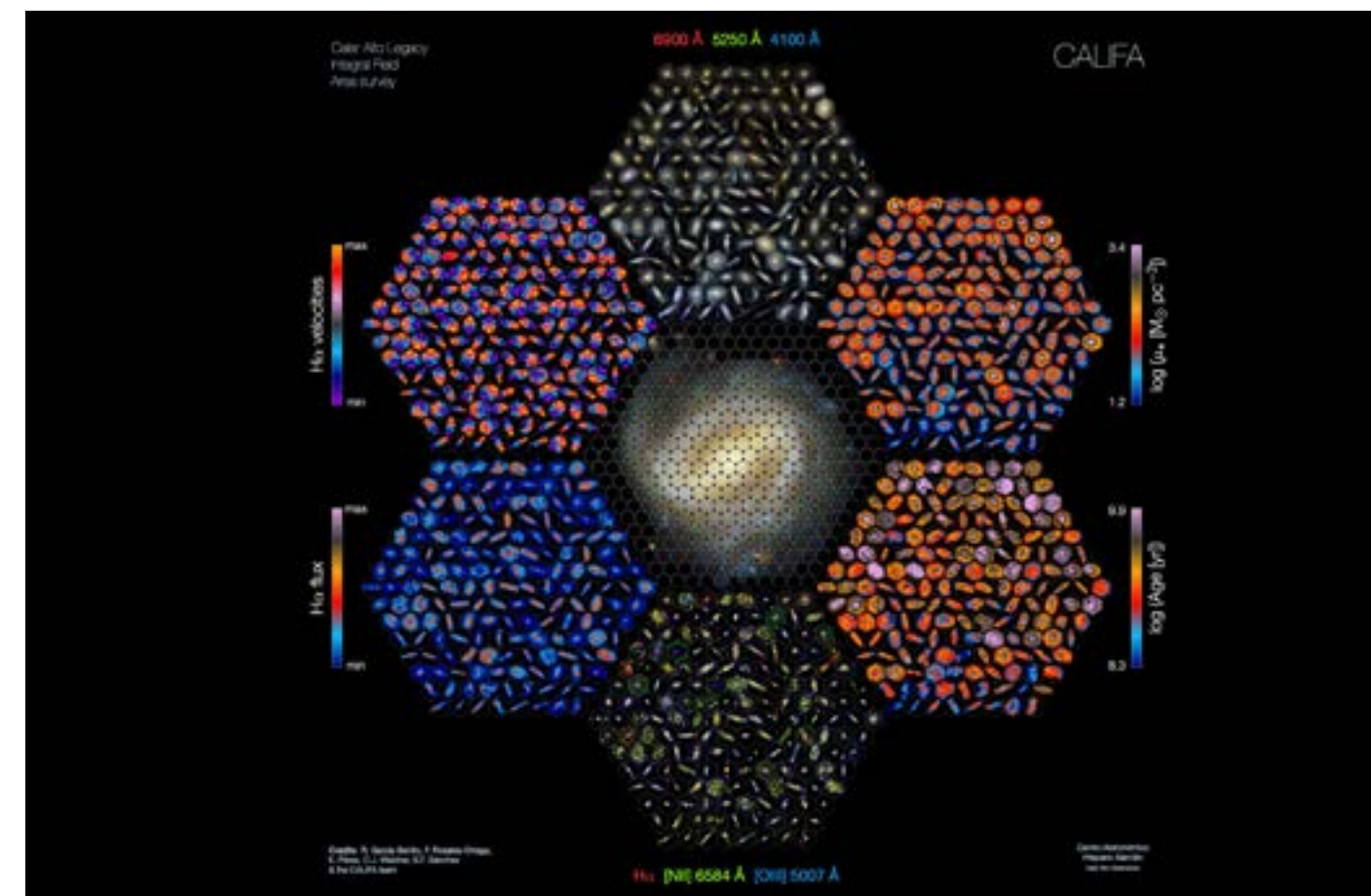
The Calar Alto Astronomical Observatory conducts a wide range of astronomy studies: the solar system, exoplanets, stars, stellar associations, galaxies, large-scale structure of the universe and cosmology. Important observational legacy projects for the international community have been carried out from Calar Alto Observatory, such as ALHAMBRA and CALIFA. The latter of the two projects obtained integral field spectroscopy data

with the PMAS/PPAK instrument in the 3.5-metre telescope, which has generated high-quality maps of stellar velocities in galaxies, among other data. Thanks to these maps, an international team has created a library of orbital movements of stars for a sample of 300 galaxies of the main morphological types within a wide range of masses. This library of galaxy histories is currently the largest obtained so far and will serve as a reference for comparing future observations and adjusting cosmological formation and evolution models of galaxies (16).

In addition to that, various exoplanets have been detected thanks to measurements obtained with the spectrograph CARMENES, which is also installed in the 3.5-metre telescope. This has been possible thanks to the high resolution and

stability of the instrument that allows us to detect the movement that a planet with a mass similar to the Earth's mass causes in red dwarf stars, thus revealing its presence. Among the exoplanets discovered thanks to CARMENES we can highlight: the superearth that orbits the Barnard's Star, which is the second closest stellar system to the Earth (17); the two planets in the habitable zone of Teegarden's Star, with masses very similar to the Earth's mass (18); and a giant planet around a red dwarf star, a fact not predicted by classical models of planetary formation (19). The technology developed for the CARMENES spectrograph will not only lead to future discoveries but will also help society with future industrial and technological applications.

A composition of panels depicting maps of some of the properties of galaxies obtained from CALIFA data. Credits: R. García-Benito, F. Rosales-Ortega, E. Pérez, C.J. Walcher, S.F. Sánchez and the CALIFA's team







ASTRONOMY  
INFRASTRUCTURES  
NETWORK (RIA)

## IRAM 30m TELESCOPE (IRAM 30m)

The 30 metre telescope is one of the two observatories of the Institut de Radioastronomie Millimétrique (Institute of Millimetric Radio Astronomy, IRAM). This institute is a collaboration between the French CNRS (National Centre for Scientific Research), the German MPG (Max Planck Society) and the Spanish IGN (National Geographic Institute). At an altitude of 2,850 metres at Pico Veleta (Sierra Nevada, Granada), it is currently one of the world's largest and most sensitive radio telescopes for tracing millimetre waves. It is a 30m classic parabolic antenna that is unrivalled in terms of sensitivity and its panels can be adjusted to a precision of 55 micrometres, an ideal paraboloid.

The telescope is equipped with three high-performance instruments: EMIR is a heterodyne receiver with four bands each

with two polarisations, which operates in 3, 2, 1 and 0.8 mm atmospheric windows (90, 150, 230 and 330 GHz), with a bandwidth of 16 GHz. HERA is a heterodyne receiver with two arrays of 3x3 pixels to detect radiation on two polarisations on a 1 mm (230 GHz) band. The heterodyne instruments are complemented by three high-capacity and high-resolution spectrometers (FTS, WILMA and VESPA). These instruments are primarily used for molecular gas mapping in our galaxy and in near and distant galaxies. The latest addition to the set of instruments at the 30m telescope is NIKA2, a camera for continuum observation in the 1 and 2 mm bands, which uses the new KID technique (kinetic induction detectors). The instrument's three large arrays of detectors (totalling almost 3,000 pixels) are cooled at 150 mK. The KID technology means that this instrument is

currently unique because of its design and performance. NIKA2 is fundamentally designed to observe dust emissions in nearby molecular clouds and galaxies up to the most distant (and youngest) in the known universe. It is also used for studying galaxy clusters by means of the Sunyaev-Zel'dovich effect.

The IRAM 30m telescope actively participates in the VLBI network (very-long-baseline interferometry), the GMVA network (Global Millimetre VLBI Array) and the EHT network (Event Horizon Telescope). The VLBI technique makes it possible to synthesise a "virtual telescope" as big as the Earth with the main aim of being able to observe in detail objects that are seemingly very small. This "virtual telescope" was made possible thanks to access to the best radio telescopes at millimetre wavelengths in

the world, and with the fundamental involvement of the ALMA radio telescope. One of the latest projects that this radio telescope has taken part in, together with the 40-metre telescope in Yebes, the two largest in Spain, was to obtain the clearest image of our galaxy's black hole, known as Sgr A\*. Due to the distance between our planet and the centre of the Milky Way, the apparent size of this black hole in the sky is less than a hundred-millionth of a degree, similar to the size of a tennis ball on the Moon's surface, as seen from Earth. Future observations at a higher frequency will soon provide crucial information about the processes and dynamics surrounding this object and will provide the key to better understanding the objects that are currently the most distant in the known universe (20).

In lower box.-Top left: simulation of Sgr A\* at 86 GHz without interstellar scattering. Top right: simulation with interstellar scattering. Bottom right: observed image of Sgr A\*. Bottom left: observed image of Sgr A\* after removing the effects of interstellar scattering. Credit: S. Issaoun, M. Mościbrodzka, Radboud University/ M. D. Johnson, CfA







ASTRONOMY  
INFRASTRUCTURES  
NETWORK (RIA)

## YEBES OBSERVATORY (YEBES)

[www.astronomia.ign.es](http://www.astronomia.ign.es)



The Yebes Astronomical Centre (Spanish National Geographic Institute, Ministry of Development) is devoted to developing and constructing instrumentation in the field of radio astronomy, as well as astronomical observations that are of astronomical, geodetic and geophysical interest. Located 80 km from Madrid in the town of Yebes (Guadalajara) and at an altitude of 980 metres, the centre hosts two essential scientific-technical installations: the 40 m telescope and the 13.2 m telescope belonging to the RAEGE network (Spanish-Portuguese Atlantic Network of Geodynamical and Space Stations) and the VGOS international network. The 40 m telescope is one of the most important nodes of the European VLBI Network (EVN), and it also belongs to the Global Millimetre VLBI Array Network (GMVA) and the International VLBI Service (IVS). Its outstanding facilities

include the high-tech microwave laboratories and a gravimeter. Its three geodetic techniques, radio astronomy VLBI, gravimetry and GNSS, and in the near future an SLR pulsed laser station, means the Yebes Observatory is considered a core geodetic station.

One of the most important discoveries in which the Yebes 40m telescope has taken part within the EVN was the detection of gas jets at close to the speed of light produced by the fusion of two neutron stars.

The biggest stars end their lives in a gigantic explosion known as a supernova. Sometimes, the inert nucleus survives and becomes known as a neutron star because it is small and extremely dense. When these stars live in a pair, they tend to fall in a spiral together, leading to catastro-

phic consequences: their collision is one of the most violent phenomena in the universe meaning we can detect their gravitational mark even if it occurs hundreds of thousands of light years away (21).

Another recent and important outcome is the most detailed and sensitive known image of the black hole at the center of our galaxy, SgrA\*. Such image, published in 2019, was obtained with the GMVA in which the 40m radiotelescope participates regularly as a node.

The center of our galaxy hosts a super-massive black hole with an equivalent mass of 4 millions solar masses around which a group of stars, trapped by its huge gravitational field, orbit at high speed. Black holes are surrounded by an accretion disk with matter that falls into it and by matter

fleeing at speeds close to the speed of light in opposite directions along jets perpendicular to the disk. Until now we do not know the orientation of SgrA\* and therefore we do not know if the image observed comes from matter in the disk or from one of the jets pointing towards the Earth (20). Observations towards SgrA\* will continue in the future at higher frequencies although the rapid variability of its emission makes it very complex to obtain an image of the black hole as that one from M87\*, that helps to understand its orientation and nature.

The study of these energetic phenomena in regions with extreme physics expands the horizons of our knowledge on this subject and increases our understanding of the universe we live in.

Artist's impression of the merger of two neutron stars with all the material expelled into space and the observed jet after breaking through this shell. Credit: Beabudai Design.







ASTRONOMY  
INFRASTRUCTURES  
NETWORK (RIA)

## JAVALAMBRE ASTROPHYSICAL OBSERVATORY (OAJ)

[www.oajweb.cefca.es](http://www.oajweb.cefca.es)



The Javalambre Astrophysical Observatory (OAJ) is an astronomical observatory built and operated by the Centro de Estudios de Física del Cosmos de Aragón (CEFCA). It is located on the summit of the Pico del Buitre at an altitude of 1956 m and within the municipality of Arcos de las Salinas. The observatory's main purpose is the compilation of large scale multi-filter astronomical surveys used as the basis for leading-edge research on astrophysics and cosmology.

Facilities include control rooms, laboratories, several support telescopes that perform sky quality control and two main next-generation telescopes: the Javalambre Survey Telescope (JST aka T250 which has an aperture of 2.55 m and a field of view of 3 degrees and the Javalambre Auxiliary Survey Telescope (JAST aka T80) which has an aperture of 83 cm and a field of view of 2 degrees. The ini-

tial science instrumentation consists of two wide-field panoramic cameras: JPCam, with a 5 square degree effective field of view, and T80Cam, with a 2 square degree effective field of view. Attached to the cameras are multi-filter trays that allow imaging on several spectral bands, effectively generating low-resolution spectra for every sky pixel.

Together, telescopes and cameras have allowed OAJ to carry out the J-PLUS survey. This is the first multi-photometric wide-field survey. That is, the first survey that provides a map of a large section of the sky and measures, in a systematic and non-selective fashion, each detected source in twelve optical spectral ranges or 'colours'. For thousands of square degrees of the sky, this is the first time that such multi-colour data is gathered. So far, J-PLUS has accurately measured the

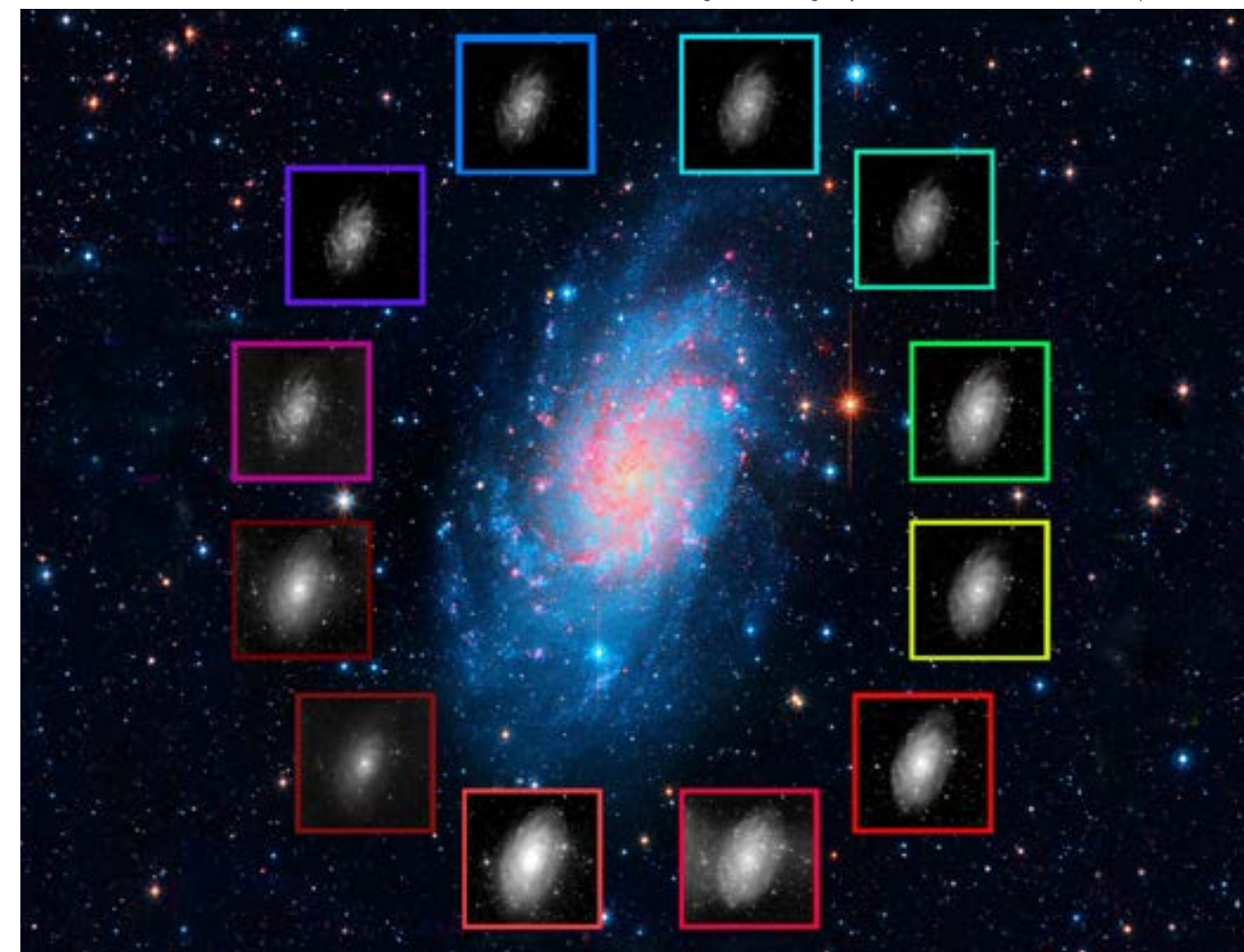
spectrum of more than thirteen million astronomical objects. This data should prove invaluable in a wide range of research areas such as the study of the solar system, the physics of stars, the compression of the Milky Way (our own galaxy), stellar formation in the nearby universe or the properties of supermassive black holes at cosmological distances (22).

To properly understand the various astronomical objects observed (be they asteroids, stars, galaxies or supermassive black holes) we need to study the light arising from such objects on several wavelengths or 'colours'. The most precise way to do this would be by measuring the spectrum of each source. Unfortunately, for such a large number of objects, this would be prohibitively expensive in terms of the observation time required and would necessitate a pre-selection of what

sources to observe which, in turn, would unavoidably bias any scientific interpretation of the resulting data.

At OAJ, an entirely different approach is followed: large areas of the sky are observed using wide-field cameras sensitive to a multitude of spectral ranges or 'colours' and, in this way, a low-resolution spectrum is obtained for each and every source detected, thus avoiding any possible selection bias. Although the low resolution of the spectra clearly impairs the ability to make detailed measurements of the changes of intensity as a function of wavelength, the photometric spectra obtained at OAJ are, nonetheless, of sufficient resolution to obtain valuable physical information about the vast number of sources observed.

Image of the M33 galaxy in colour and in the 12 J-PLUS filters (Credit: CEFCA).



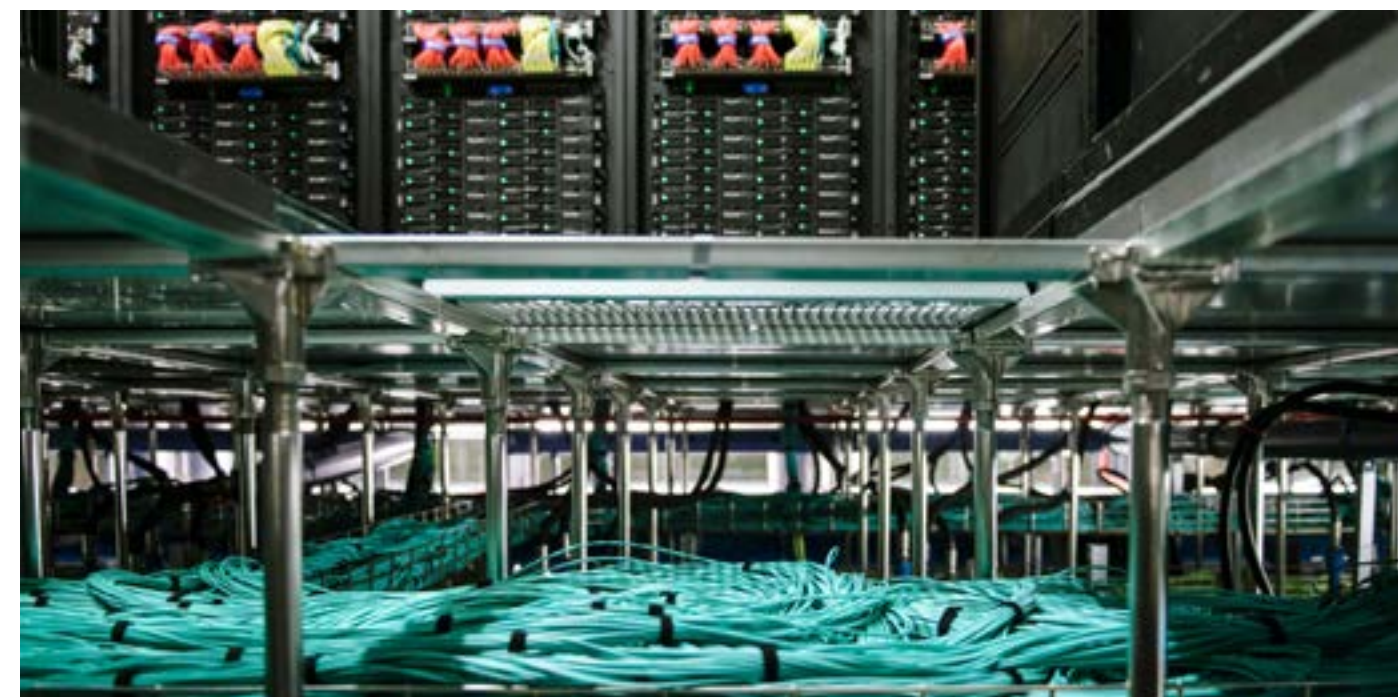




@CESGA

## e-SCIENCE NETWORK

- ◆ SPANISH SUPERCOMPUTING NETWORK (RES)
- ◆ RedIRIS



In the previous edition of the ICTS Map, the Advisory Committee of Unique Infrastructures (CAIS) recommended creating the e-Science Network, which initially consisted of the Spanish Supercomput-

ing Network and RedIRIS, as well as other institutions and users in this field.

Creating this ICTS Network will encourage Spanish R&D&I infrastructures fo-

cused on e-Science to coordinate and cooperate, and will advise the Ministry of Science, Innovation, and Universities on these matters that are developing so notably in Europe and across the world.



@Alfonso Esteban





e-SCIENCE  
NETWORK

## SPANISH SUPERCOMPUTING NETWORK (RES)

www.res.es



The Spanish Supercomputing Network was created in 2006 by the Ministry of Science and Innovation as a response to the Spanish scientific community's need for greater computing capacity and access to intensive computing resources, as supercomputing resources are a critical asset for the scientific and technological development of Spain. The RES is an infrastructure of supercomputers situated in different locations, and each one contributes to the total processing power available to the users of different R&D groups. This network not only provides supercomputing resources, but also provides users with a technical support service, as well as specific training and diverse activities with the aim of improving the efficient use of resources and expanding the use of supercomputing in all research areas.

The supercomputers that currently form part of the RES are:

- **MareNostrum and MinoTauro from the Barcelona Supercomputing Center-Centro Nacional de Supercomputación (BSC-CNS, Barcelona).** This centre was

officially founded in 2005 by the Spanish government, the regional government of Catalonia and the Universitat Politècnica de Catalunya (UPC). It specialises in High Performance Computing (HPC). It is the coordinator of the RES, providing it with 40% of the computing power of MareNostrum (450 million CPU hours per year) and 60% of that of MinoTauro (over two million CPU hours per year).

- **Finis Terrae Supercomputer from the Galicia Supercomputing Centre (CESGA, Santiago de Compostela).**

This is an institution that is co-owned by the regional government of Galicia and

the Spanish National Research Council (CSIC). Finis Terrae provides the RES with 20% of its computing power.

- **Pirineus from the Consorci de Serveis Universitaris de Catalunya (CSUC, Barcelona).** This consortium is made up of the regional government of Catalonia and 10 Catalan universities, and provides the RES with 20% of its computing power.

- **Tirant at the University of Valencia (UV) is installed on the Burjassot campus and is managed by the computing service at the UV (SIUV).** It allocates 50% of its computing capacity to the RES.

- **Altamira at the University of Cantabria (UC, Santander), is installed in the Institute of Physics of Cantabria (IFCA), a centre belonging to the UC and**

**the Spanish National Research Council (CSIC).** It provides the RES with 20% of its resources.

- **Lusitania at the Computing and Advanced Technologies Foundation of Extremadura (COMPUTAEX, Cáceres) which is the Extremadura Centre of Research, Technological Innovation and Supercomputing.** It contributes 50% of its resources to the RES.

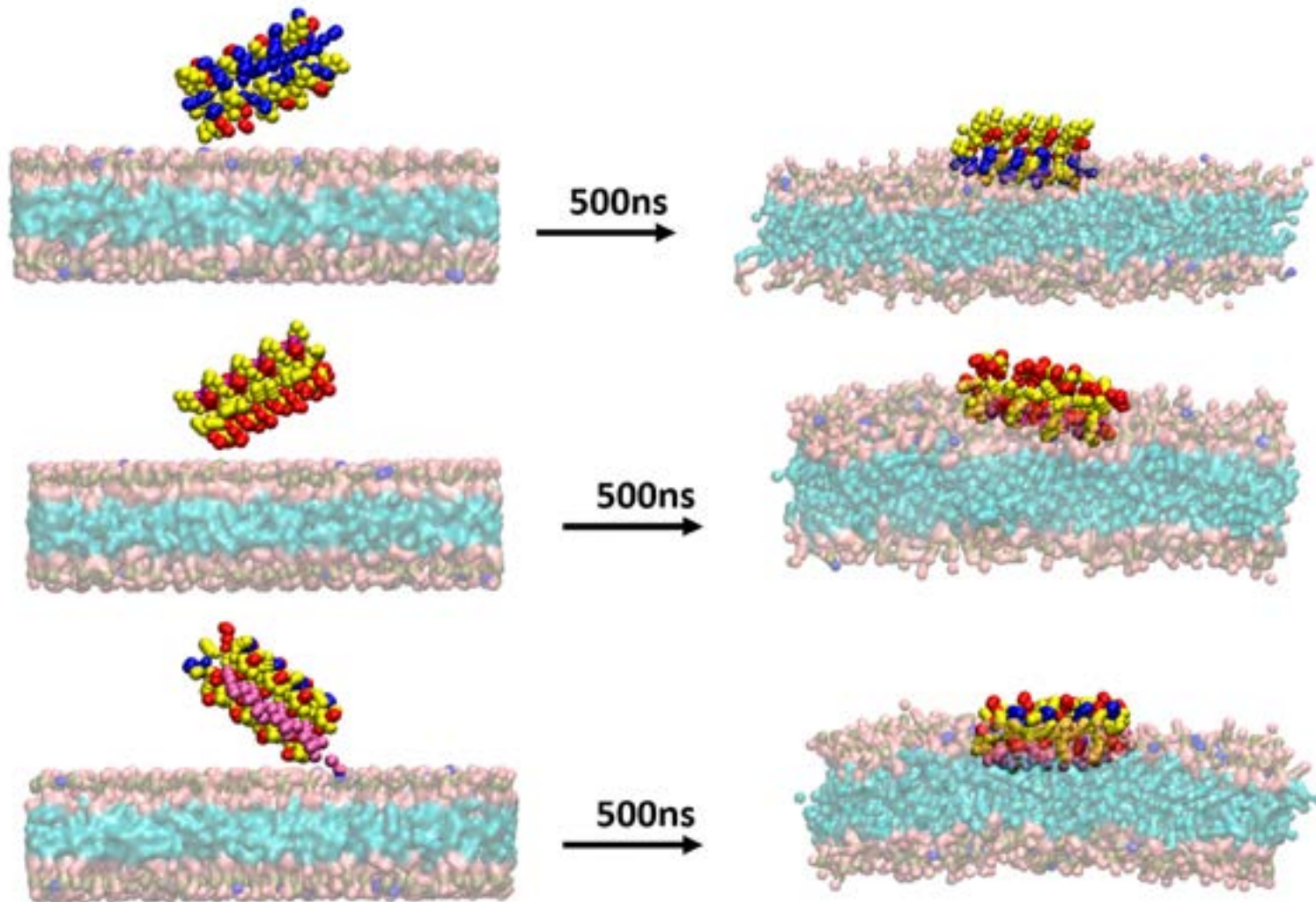
- **Picasso at the University of Málaga (UM) is located at the university's Supercomputing and Bioinformatics Centre (SCBI), which is in the Andalucía Technology Park.** It contributes 35% of its resources to the RES.

- **La Palma at the Canary Islands Astrophysical Institute (IAC), which is composed of the Spanish government, the regional government of the Canary**



@CESGA





Examples of peptide nanotubes formed by cyclic peptides with antimicrobial activity interacting with membranes of different composition  
Credit: Rebeca García Fandiño.

**Islands, the University of La Laguna and the Spanish National Research Council (CSIC).** It provides the RES with 50% of its computing power.

**- Caesaraugusta at the University of Zaragoza (UNIZAR), located at the Institute of Biocomputation and Physics of Complex Systems (BIFI), a research institute belonging to the university.** It contributes 20% of its computing power to the RES.

**- Caléndula of the Supercomputing Center of Castilla and León (SCAYLE, León), which is a public entity created by the regional government of Castilla and León and the University of León.** It contributes 50% of its resources to the RES.

**- Cibeles from the Autonomous University of Madrid (UAM, Madrid), located**

**in the Scientific Computing Centre (CCC-UAM), which provides centralised computer support to the Autonomous University of Madrid Campus.** It contributes 20% of its resources to the RES.

The RES provides high-performance computing resources through an open, common and competitive access system. The application process is the same for all the RES nodes and is based on criteria of effectiveness, efficiency and transparency. This common access guarantees optimal use of all the resources available in the network (computing, storage, parallelization, etc.) The objective of the RES is to drive the progress of science and innovation in Spain, in any of its knowledge areas.

In the area of Materials Science, a new thermodynamic stabilisation mechanism has been discovered thanks to the MareNostrum. This mechanism makes

some structures on surfaces probable that were previously believed to be impossible because of their energy needs. To confirm this, calculations were made on the polar face of cerium oxide. This material is fundamental to the composition of the catalysts for reducing gas emissions from cars. The development has a significant impact because there are no experimental capacities able to determine this type of effect due to the difficulty and danger of working with certain chemical reactions. So, modelisation is the only way to increase knowledge (23).

Modelisation also plays a fundamental role in the area of the environment. The climate models used to generate information in the short and long term to adapt and mitigate climate change are subject to errors from various sources, including from the instruments used to detect and characterise climate signals

such as satellites, buoys, weather stations, etc. Using climate simulations as an independent source to assess the quality of the observational data, a better understanding of all the models with observational databases based on satellite data has been found, in contrast to those generated solely using data from ships and buoys. Satellite data, with its global coverage, greater spatial resolution and fewer instrumental and processing errors, provides more precise estimates than the local measures scattered across the planet. These results provide an objective measurement for assessing the investments in monitoring the state of the global climate system, such as the Copernicus programme, which is mainly based on generating and using satellite information (24).

Copernicus is the most ambitious Earth observation programme ever. It is de-

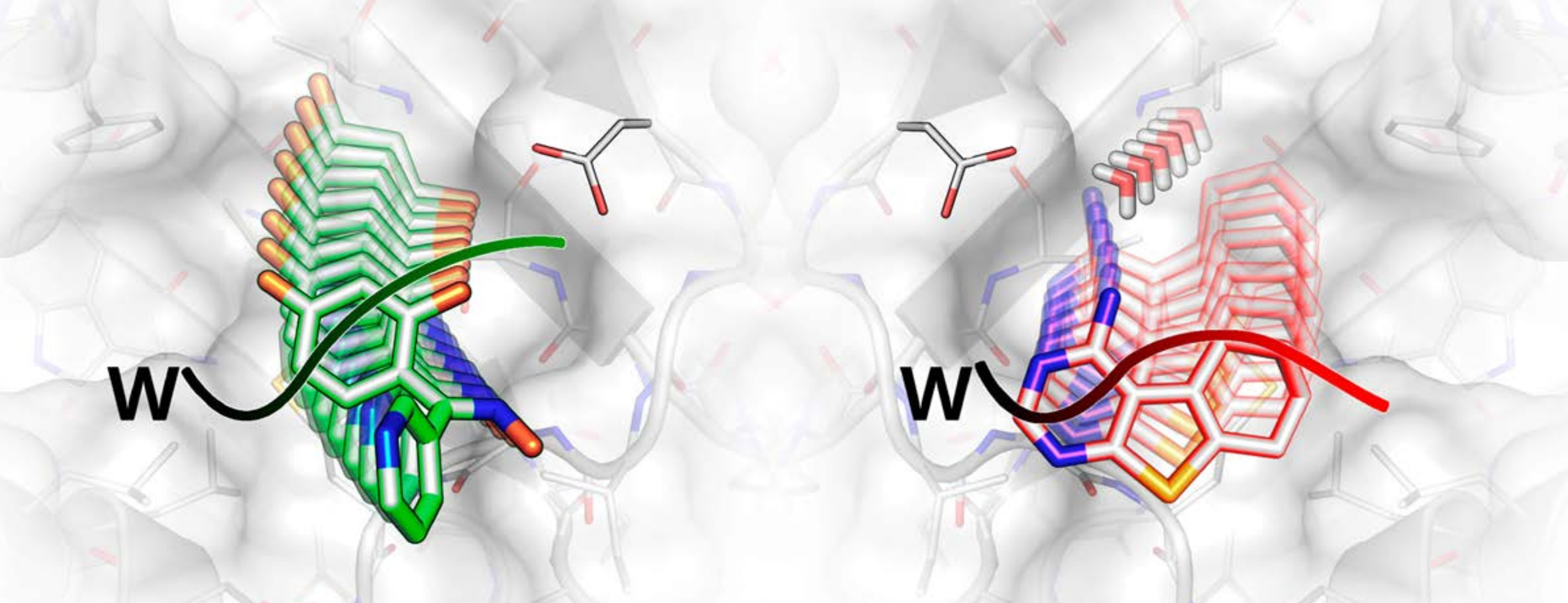
signed to provide information to improve the management of the environment, mitigate the effects of climate change and guarantee human safety. It is led by the European Commission in partnership with the European Space Agency. This programme offers six types of service, including the Copernicus Marine Environment Monitoring Service (CMEMS). This provides open access to information products about the state of the marine environment, both for the entire ocean and regional European seas, and one of the RES supercomputers is involved in this. Over 5,000 direct users, including heads of maritime traffic control, people working in the fishing industry, port authorities and European civil protection services, are informed daily of the forecast state of the sea thanks to the oceanographic simulation carried out daily using the Finis Terrae supercomputer. The size of the area for this simulation and the spa-

tial resolution of the grid that defines it require computing resources that are merely proportional for a large infrastructure with unique characteristics. Furthermore, as it is a daily operation that provides critical information for the organisation and security of a plethora of human activities, this service can only be provided by an organisation capable of ensuring the infrastructure is permanently available.

In the field of Biomedicine, and regarding the use and abuse of antibiotics and the bacteria's consequent development of resistance to these antibiotics, the Finis Terrae supercomputer has been able to interpret the interaction mechanism between different molecules with the cellular membrane. This has led to the proposal of a rational design of antimicrobial compounds that are more efficient and selective than conventio-







nal antibiotics. Recent progress in the power of supercomputers and the algorithms implemented in the molecular dynamics software packages has made it possible to reach the required resolution. These studies generate a huge amount of data that would be unmanageable without supercomputing (25).

Improvement in the effectiveness and efficiency of drug discovery is a key objective in biomedical research. This process looks for molecules that can be connected to a target protein and modify how it functions to achieve a therapeutic effect. This process normally focuses on studying the balanced position, in other words, two molecules that form the best possible interactions. Thanks to the

MinoTauro and MareNostrum supercomputers, a new estimation method using a different principle has been developed, applied and verified. The new aspect lies in the fact that the method, known as Dynamic Undocking, studies how the medication-protein compound will be broken, which are the breaking points and how these molecules can be improved to make their connection more resistant. This method can be used to complement existing techniques, enabling advances in the design of new molecules: the effectiveness of the best current processes improves fivefold with a reasonable computational cost. In fact, it is already being applied successfully in various projects relating to cancer and infectious diseases, among others. Al-

though each molecule considered in this model takes a couple of hours of computing, the medication discovery processes need to assess thousands and even millions of candidate molecules. That is why its practical application requires a unique infrastructure (26).

Conceptual representation of the initial dissociation of two molecules from the same binding site. The one at the left-hand side is structurally stable and a lot of work is needed to break native contacts. This is a signature of true ligands and the molecule was confirmed to be active. The right-hand side molecule forms good interactions and is predicted as active by existing methods, but its interaction is not difficult to break, indicating that it is in fact a false positive. Application of this concept to virtual ligand discovery can remove up to 80% of the molecules that are predicted as active by state-of-the-art computational methods (26).







e-SCIENCE  
NETWORK

RedIRIS

@Alfonso Esteban

RedIRIS is the Spanish National Research and Education Network (NREN). It provides advanced communication services to over 500 institutions in the scientific and educational community (especially universities, science centres and ICTS). The RedIRIS headquarters are in Madrid.

RedIRIS is an infrastructure belonging to the Ministry of Science, Innovation and Universities, which has delegated RedIRIS responsibilities to Red.es, a public entity belonging to the Ministry of Economy and Business. Red.es is the public agency in charge of promoting the digital transformation of Spain and is managing RedIRIS since 2004.



RedIRIS was founded in 1988 with the aim of providing universities and science centres with their own communications network, through which a large amount of information could be transferred in a controlled, efficient and secure way, and in turn facilitating remote collaboration between these centres and their participation in national and international projects, in particular e-science projects, which require massive data transfers.

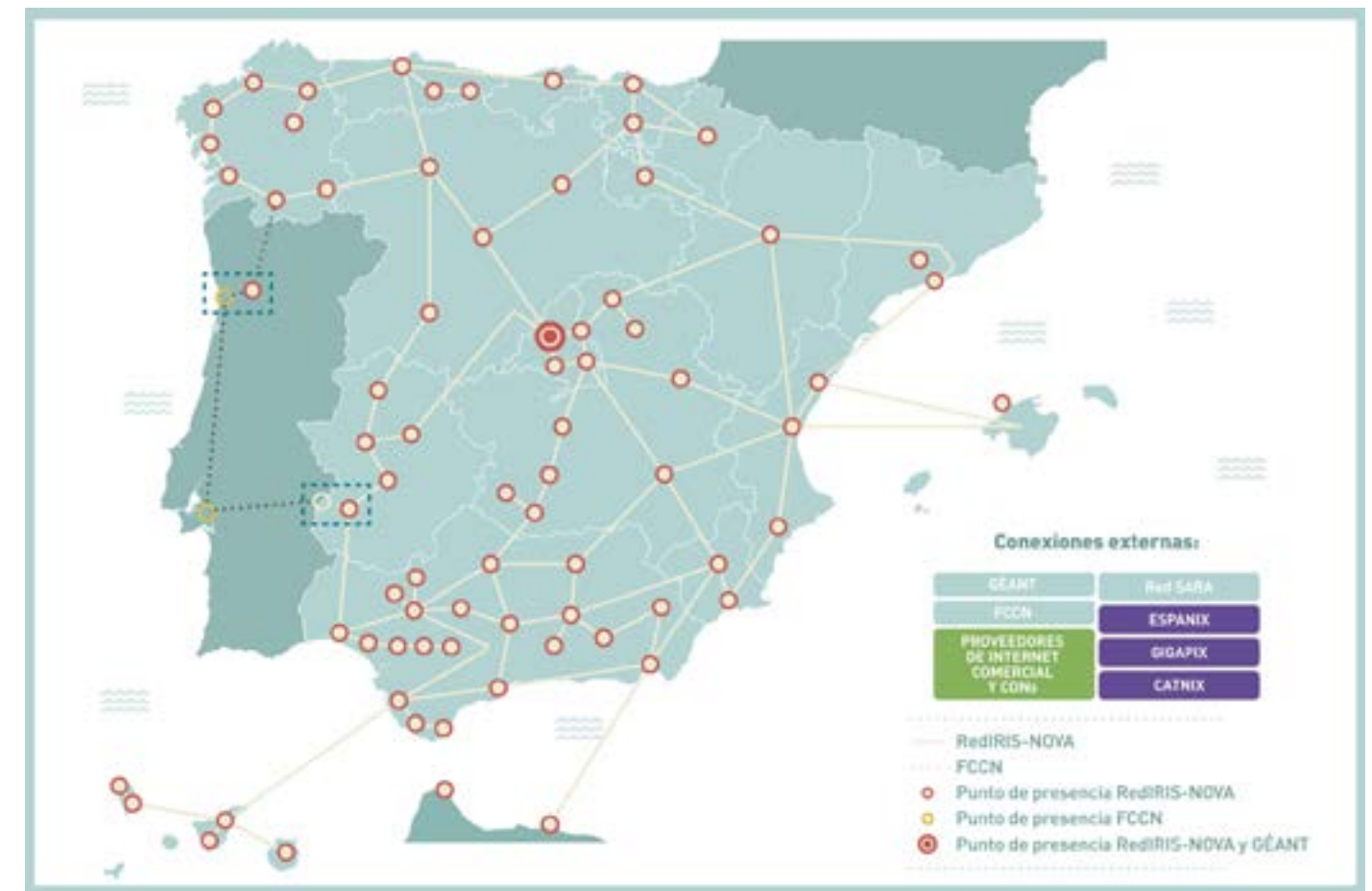
In order to provide these advanced connectivity services, RedIRIS currently manages a fibre-optic network of about 15,000 km (including over 2,000 km of underwater lines), with over 70 Points of Presence across all the autonomous communities in Spain. This modern infrastructure provides significant technological progress in capacity (almost unlimited) and flexibility, which facilitates national and international collaboration. Thanks to this powerful network, RedIRIS can pro-

vide its affiliated institutions with multiple 10 Gbps (10,000 Mbps) channels, and these will become 100 Gbps channels when the optical equipment renovation finishes.

RedIRIS provides its services in close collaboration with other regional and international education and scientific networks. The international networks include the pan-European education network GÉANT, which RedIRIS assists through management, and through which it is connected to the national research and education networks (NREN) from other European countries and research networks from other continents: Internet2 (USA), RedCLARA (Latin America), EUMEDCONNECT (North Africa), TEIN (Asia Pacific), etc. RedIRIS connects universities and research centres, covers the advanced connectivity needs of research projects such as the LHC (Large Hadron Collider) at CERN; ELIXIR (Life Sciences) or VLBI (Radio Astronomy), and

provides access to scientific instruments and resources such as telescopes on the Canary Islands, the Doñana Biological Reserve, the Spanish Supercomputing Network, etc.

RedIRIS also provides other IT services to the educational and scientific community in the fields of security (management of security incidents, mitigation of denial-of-service attacks, spam filters, digital certificates), digital identity (SIR), mobility in educational WiFi (eduroam), collaborative tools, transfer of large files, collective contracting of cloud services, support for certain electronic administration services, advice and dissemination (including events and training courses).







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## SPANISH ANTARCTIC FACILITIES (BAES)

- ◆ JUAN CARLOS I ANTARCTIC STATION (JCI)
- ◆ GABRIEL DE CASTILLA ANTARCTIC STATION (GDC)

Spanish infrastructures in polar regions are limited to those operating in the Antarctic: the Juan Carlos I Antarctic Station (BAE JCI) and the Gabriel de Castilla Antarctic Station (BAE GdC). Both are located on the archipelago of the South Shetlands and are in operation during the austral summer. Coordination of activities at both stations is carried out under the authority of the Spanish Polar Committee, with the Marine Technology Unit of the Spanish National Research Council (UTM-CSIC) responsible for logistical coordination.

- **The BAE JCI is located on the Hurd Peninsula of Livingston Island (62° 39' 46" S, 60° 23' 20' W).** The UTM-CSIC provides the technical and logistical support necessary to carry out scientific activities in the Antarctic.

[www.utm.csic.es/en/home](http://www.utm.csic.es/en/home)



- **The BAE GdC (latitude 62° 55' S and longitude 60° 37' W)** is located

on Deception Island and is run by the Army in terms of operational aspects and the UTM-CSIC in terms of scientific instrumentation and logistical management.

[www.ejercito.mde.es/unidades/Antartica/antartica/index.html](http://www.ejercito.mde.es/unidades/Antartica/antartica/index.html)



The South Shetland Islands and the Antarctic Peninsula are located in one of the regions on the planet where the temperature has been rising more quickly, up to 2.5°C in recent decades. It is essential to study the effects of climate change in the areas that could be most affected and particularly in areas like the polar regions that may have a global impact on the planet. In both scientific stations research regarding the atmosphere, glaciology, climate, global change, geomagnetism, biodiversity, natural risks, volcanic monitoring, astrobiology, geology and ecology is carried out.

With participation and support from the two Spanish Antarctic bases the populations of Antarctic penguins have been monitored

and changes in their populations have been found. These changes are in line with what is expected in a situation of global change in which some species are promoted (gentoo penguin, *Pygoscelis papua*) and some others are less successful (chinstrap penguins, *Pygoscelis antarcticus*). The research carried out has enabled the identification of various physiological mechanisms that could explain the causal relations between the increase in temperature, the potential effects of a change in diet, effects on the presence of parasites and diseases through immune response and the effects of increased human activity on the presence of contaminants and its effects on Antarctic penguin populations. The information obtained assesses the environmental changes occurring in the Antarctic and Austral Ocean by using Antarctic penguins as sentinels of the marine environment, enabling the extrapolation of this information to other ecosystems.

Meanwhile, by using meteorological data recorded on a glacier situated close to the







@UTM\_CSIC

BAE JCI and measuring the accumulated snow and melted snow and ice every year, a model has been created that can predict the amount of fusion depending on the environmental temperature of this area during summer. This model allows quantifying the

fusion sensitivity to variations of different environmental parameters, including the high sensitivity to changes in environmental temperature. The model shows that a 0.5°C increase in summer mean temperature would represent a fusion rate increase

of 56% and a fusion rate decrease of 44% if there is a similar decrease of the summer mean temperature. Through observation, it has also been confirmed that this has been happening on the glacier itself since 2001. Although this region of the planet suffered

from strong warming over the second half of the 20th century, it experienced sustained cooling over the first 15 years of the 21st century, which is an anomaly in the current context of global warming. This regional cooling has resulted in the glaciers

in this region are reducing the rate at which the ice mass is being lost due to glacier ice melting (27, 28).



@Andrés Barbosa







@Armada Española

## SPANISH OCEANOGRAPHIC FLEET (FLOTA)

- ◆ OCEANOGRAPHIC RESEARCH VESSEL HESPÉRIDES
- ◆ CSIC OCEANOGRAPHIC RESEARCH VESSELS
- ◆ IEO OCEANOGRAPHIC RESEARCH VESSELS
- ◆ SOCIB OCEANOGRAPHIC RESEARCH VESSEL



@Armada Española

The ICTS FLOTA is composed of 10 oceanographic vessels, each with technical management and financing from the Spanish government. These oceanographic vessels primarily provide services to campaigns carried out within the framework of the Spanish Strategy for Science, Technology, and Innovation and the framework programme of the European Union, as well as the specific responsibilities assigned to different Public Research Organizations of the Ministry of Science

Policy Coordination. The on-board technical support of the oceanographic vessels of the campaigns regulated by the Commission for Coordination and Monitoring of Oceanographic Vessels Activities (COCSABO) is provided by the Marine Technology Unit of the Spanish National Research Council (CSIC) and/or staff of the Spanish Oceanographic Institute (IEO) in their campaigns.

- The oceanographic research vessel Hespérides of the Spanish Navy.

- The oceanographic vessels that are financially part of or are loaned to the CSIC,
- The oceanographic vessels that are financially part of IEO,
- The oceanographic vessel belonging to the Coastal Observation System of the Balearic Islands (SOCIB) consortium.



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@Armada Española

#### OCEANOGRAPHIC RESEARCH VESSEL (R/V) HESPÉRIDES

The R/V Hespérides entered into service in 1991 and since then has carried out more than 120 oceanographic campaigns in the Antarctic, Arctic, and in the Pacific and Atlantic Oceans. In 1995, due to the important role it plays in the field of oceanographic research, it was recognised as a Major Scientific Facility by the Advisory Commission for Major Scientific Facilities, currently known as Unique Scientific and Technical Infrastructures (ICTS). The R/V Hespérides is a vessel integrated into the Maritime Action Force (FAM) of the Spanish Navy, based in Cartagena (Murcia). Its scientific equipment is completely managed by the Marine Technology Unit of the CSIC.

Its hull is reinforced for navigating the polar areas of the Antarctic and the Arctic. Its main activity focuses on austral summers, carrying out scientific research campaigns in the Antarctic and providing

support to Spanish Antarctic Facilities and their research projects. The rest of the year its activities are primarily carried out in the Atlantic, Pacific, and Mediterranean, providing support to different scientific campaigns, as well as the mapping programme of the Exclusive Economic Zone of the Ministry of Defense. It is a global research vessel with instruments and laboratories that allow for the research of natural resources and risks, global change, marine resources, global ocean currents, and marine biodiversity.

Some of the recent campaigns have allowed the circulation of water bodies and the transport of physical and biogeochemical properties in the southern hemisphere of the Atlantic Ocean to be studied by analyzing the connections between the southern Atlantic Ocean and the tropical Atlantic Ocean, with specific focus on the property exchange mechanisms in the two areas of study: the retroflexion of the Brazil-Falkland Confluence Zone and the equatorial retroflexion of the North Brazil Current.

The results identify the Brazil-Falkland Confluence Zone as an effective barrier in the shallowest layers of the sub-Antarctic and subtropical regions, but that it allows sub-Antarctic waters to sink beneath central waters and recirculate within the subtropical gyro towards the Confluence Zone itself. As it gets closer to the equator, the North Brazil Current does not undergo a sudden retroflexion, in contrast to what has previously been described. Instead, the waters of this current are gradually incorporated into the Equatorial Surface Current. During this process, waters from the tropical gyro of the north Atlantic are added, making this retroflexion a mixing and recirculation mechanism between waters from the two hemispheres.

This project represented Spanish oceanography's strong presence in regional and transatlantic studies of circulation and flows, while also clearly demonstrating this vessel's capacity to carry out an observational coverage of the

south Atlantic that is of great scientific and geostrategic interest to Spain.

[www.utm.csic.es/hesperides](http://www.utm.csic.es/hesperides) 

#### CSIC OCEANOGRAPHIC RESEARCH VESSELS (R/V)

**The R/V García del Cid** was launched in 1979. It is a vessel specifically used for marine science research and is at the service of national and international groups that carry out oceanographic research. Its main areas of work are the western Mediterranean, the Iberian area of the Atlantic, and the Canary Islands. It is based in the port of Barcelona. The vessel's equipment allows for marine research into oceanography, geology, and geophysics, as well as experimental fishing research using benthic and pelagic techniques and research into phytoplankton, zooplankton, and ichthyoplankton. The vessel is equipped with both wet and dry laboratories, A-frames and winches for working on the deck (20 m<sup>2</sup>) and diverse acoustic equipment, and has good maneuvering ca-

pabilities for anchoring and the recovery of buoys, current meters, sediment traps, etc.

**The R/V Mytilus**, launched in 1997, is based in the port of Vigo (Pontevedra). It is a coastal research vessel and its research work is mainly focused on the area of Galicia, although it occasionally carries out work in other areas of the Iberian Peninsula and the Canary Islands. It is designed for the study of marine biology, physical oceanography, and marine geology.

**The R/V Sarmiento de Gamboa** was launched in 2006, and focuses on the study of global ocean currents, marine biodiversity, fishing resources, and climate change. It features scientific and technical equipment for carrying out research into marine geophysics, oceanography, biology, and geochemistry. It also possesses advanced technology for navigation systems (such as dynamic positioning), and was the first Spanish oceanographic vessel able to work with Remote Operated Vehicles (ROVs) for deep sea. It is currently the only vessel in the fleet with the

capability to carry out geophysical research in accordance with the current standards of the exploration industries.

In fact, the characteristics of this vessel have enabled Spain to take part in the GO-SHIP programme with a biennial series of oceanographic campaigns that have recorded the oceanic acidification in the water bodies of the north Atlantic. A comprehensive observation of the currents and physical properties of an entire column of water has been carried out. It measured the chemical properties of the water (system of carbon dioxide, dissolved oxygen, organic matter, nutrients, chlorofluorocarbons and nitrous oxide) in a series of one hundred stations stretching from the Iberian peninsula to Greenland. The results show that the acidification rates in the deep layers (>1,000 metres) are very similar to the rates observed on the ocean surface. If the current rates of atmospheric CO<sub>2</sub> increase are maintained, oceanic acidification will mean that 70% of the coral reefs in the deep



@IEO





areas of the North Atlantic will be living in waters that are corrosive for their limestone structures in under 40 years. These reefs are delicate deep-sea ecosystems with thousands of years of history (29)



[www.utm.csic.es](http://www.utm.csic.es)



#### IEO OCEANOGRAPHIC RESEARCH VESSELS (R/V)

**The R/V Francisco de Paula Navarro** is a versatile vessel for fishing and oceanography based in the port of Palma de Mallorca. This vessel is normally used for fishing and oceanographic campaigns along the Spanish coast, mainly in the Mediterranean. With an overall length of 30.5m, it has a total capacity of up to 17 people between the crew and scientific team. It can carry out geomorphology, hydrography, and plankton studies as well as mapping projects for benthic and pelagic habitats, protected marine areas, contamination, and assessment of ecosystems and used living resources.

**The R/V Ramón Margalef** was completed in 2011 and is specially designed for oceanographic and fishing research, including the integrated study of ecosystems. Due to its dimensions and capacity, it is classified as a regional vessel. It has 10 days of autonomy and space for 11 researchers and technicians, as well as its 14 crew members. It carries out its activities nationally or in the surrounding seas, and features the latest technology for the study of marine geology, physical and chemical oceanography, marine biology, fishing, and environmental protection.

**The R/V Ángeles Alvariño** was completed in 2012. This vessel provides the Spanish and European oceanographic fleet with a floating laboratory equipped with the latest technology. It can carry 13 researchers and technicians, as well as its 14 crew members.

Both Ramón Margalef and Ángeles Alvariño are classified as regional vessels, and have the capacity to employ the LIROPUS ROV2000. Also features a special design that ensures low levels of un-

derwater radiated noise (ICES209), allowing it to work without altering the marine life behavior. Both share cutting-edge technologies for studying marine geology, physical, and chemical oceanography, marine biology, fishing, and environmental protection. The area of operation for both is North Atlantic ocean and the Western Mediterranean Sea.

The latter two vessels effectively made their maiden voyages with an activity related to an extraordinarily spectacular event: the submarine volcano eruption near the island of El Hierro (Canary Islands) in October 2011. The birth of a submarine volcano on Spanish territory has been studied for the first time, and it became known as the Tagoro volcano. Monitoring the variability of the physicochemical properties during the different evolution stages of the volcano (pre-eruptive, eruptive and degassing) has provided very useful information for establishing the key features of its internal behavior and the disturbance to the surrounding ecosystem. This ecosystem has become a natural laboratory for studying

how marine life is able to adapt to conditions of extreme climate change (30, 31).

The Canary Islands is a sensitive area for submarine volcano eruptions. Due to the random and unpredictable nature of the eruptions, it is vitally important to suitably assess risks to maximize the safety of the nearby population centers. These activities are fundamental for learning how submarine volcanoes behave from their origin and for learning about the internal evolutionary behavior during their different stages. This is applicable to the possible generation of early-warning tools, and in many other fields.



[www.ieo.es/web/ieo/flota](http://www.ieo.es/web/ieo/flota)



#### SOCIB OCEANOGRAPHIC RESEARCH VESSEL (R/V)

The R/V SOCIB is a 24-metre catamaran built as part of the observational strategy of the Balearic Islands Coastal Observing and Forecasting System (SOCIB) consortium. This catamaran is a valuable tool for the science community and the society of the Balearic Islands as it is one of the SOCIB ICTS tools for responding to the strategic elements on the islands, such as climate change and the sustainable conservation of living resources in the Balearic Sea, optimization and management of Protected Marine Areas, and three-dimensional characterisation of the physical variability response of marine ecosystems. It is

also a key element for quickly responding to oil spills, studying the conservation of bluefin tuna and proliferation of jellyfish. Both cases are directly associated to the routine monitoring programmes in Balearic waters, which are of global importance and strategic interest as the Balearic Islands are an internationally renowned "hot spot" of biodiversity







## DISTRIBUTED BIOMEDICAL IMAGING NETWORK (ReDIB)



www.redib.net

This distributed ICTS consists of four nodes:

- **The Advanced Infrastructure in Translational Imaging (TRIMA)** is located at the National Center for Cardiovascular Research Carlos III (CNIC, Madrid) and has been in operation since 2010. It is organized into three platforms: Molecular and Functional Imaging, Advanced Imaging, and High-Performance Imaging. It is a facility with a translational mission that offers latest-generation technology for making progress in the study of different cardiovascular illnesses and diseases from molecular to tissue levels, for pre-clinical studies of small animals, with possible application to humans as well.
- **The Platform for Molecular and Functional Imaging is part of the Centre for**

### Cooperative Research in Biomaterials (CIC biomaGUNE, San Sebastián)

which opened in 2006. It was designed, constructed and equipped to carry out longitudinal and multi-modal research projects in the pre-clinical field, as well as to develop applications in the areas of Pre-Clinical Molecular and Functional Imaging and Nanomedicine.

- **The Bioimaging department at the Complutense University of Madrid (BiolmaC)** consists of the Nuclear Magnetic and Electronic Spin Resonance, Cerebral Mapping and Diagnostic Imaging facilities.

- **The Medical Imaging Department at the La Fe University and Polytechnic Hospital in Valencia** consists of the Biomedical Imaging Research Group (GIBI230) and the Experimental Radiology and Biomarker Imaging Platform (PREBI). Its mission is to promote and develop the use of imaging techniques and biomarkers to optimise the diagnostic and therapeutic efficiency of medical imaging through a multidisciplinary and multimodal approach to clinical care research and animal testing.

The equipment, staff, and organisation of this infrastructure form a dynamic collective providing service to the scientific community in the field of molecular and functional imaging, as well as advanced imaging. It includes latest-generation technology and resources for researchers in the field of biomedical imaging. Although these imaging facilities can be applied to a wide range of indications, its use in the development of novel drugs will be outlined.

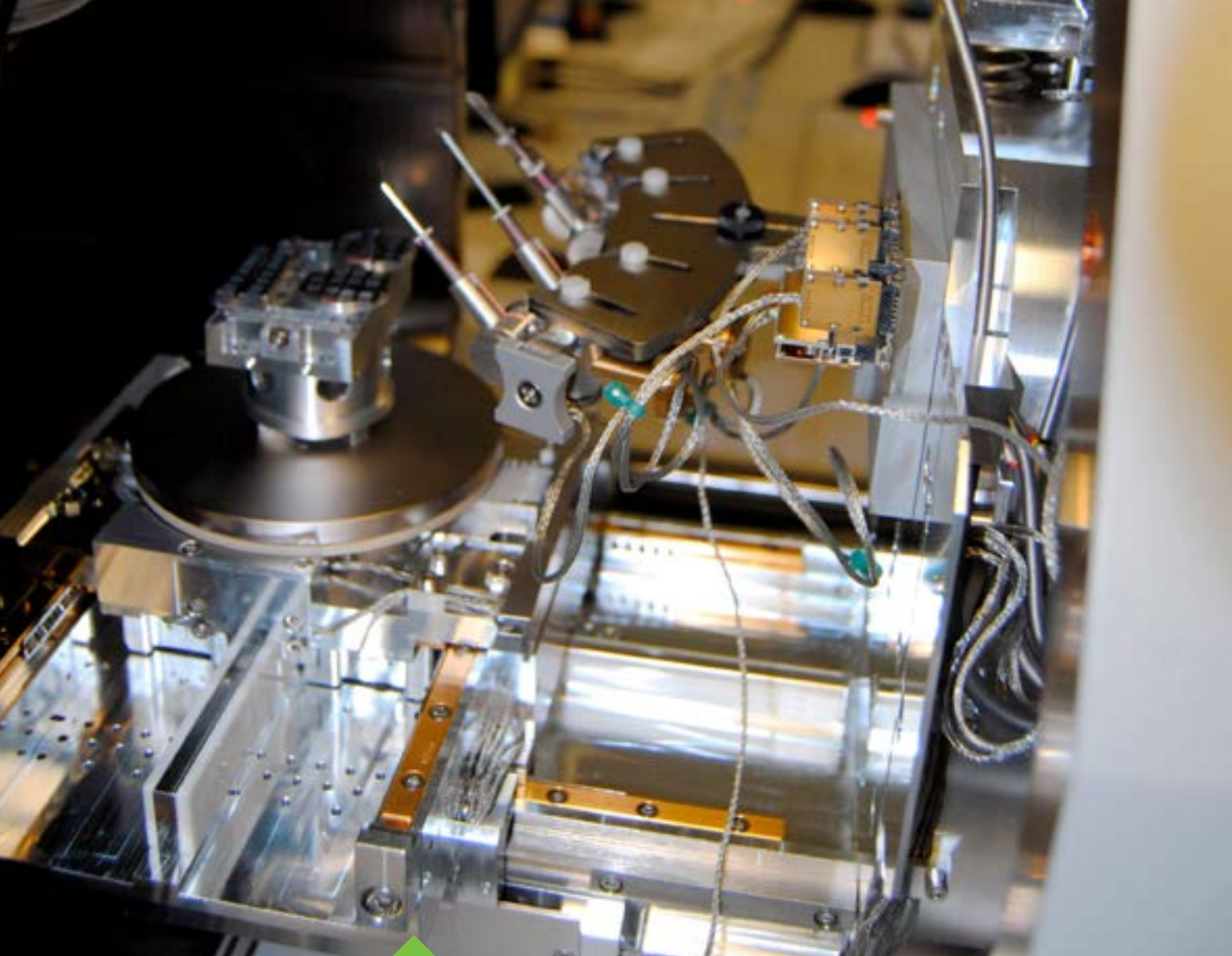
At a pre-clinical level, and using a non-invasive imaging technique such as state-of-the-art magnetic resonance, which is available on the CIC biomaGUNE Platform for Molecular and Functional Imaging, the effectiveness of a novel neurorepair therapy for cerebral infarction/stroke has been tested on mice. Stroke has a large socio-economic impact and represents the second most common cause of death among adults in Europe. Up to 14% of the registered cases are suffered while sleeping. There is no specific treatment for these patients, meaning new treatments need to be developed. Magnetic resonance is one of the leading methods in cerebral infarction research because it provides information about the state and evolution of the process, being able to monitor the treatment efficacy in a non-invasive

manner. The combination of the information obtained through this technique about the infarct size before and after the treatment, and the neurological improvement of the animal enables us to assess the efficacy of the applied treatment and its future use in humans.

At a clinical level, and thanks to 3 Tesla nuclear magnetic resonance equipment provided by the TRIMA-CNIC infrastructure, a therapeutic alternative with a better tolerance profile has been proposed in the treatment of patients with Marfan Syndrome (MS). MS is a hereditary disease that occurs in one in 3,000-5,000 births and affects the connective tissue. Around 90% of patients with MS will have cardiovascular complications throughout their lives. By using nuclear magnetic resonance and echocardiography, the effectiveness and safety of a novel drug, called losartan with fewer contraindications and side effects, can be compared to the standard treatment. The aim was to avoid aortic dilation and subsequent complications. The results of this study have provided strong scientific evidence with an international impact and have contributed to useful and relevant long-term knowledge to improve the treatment of MS patients with an alternative medication (32)







**This distributed ICTS includes four infrastructures:**

- **Spanish National Centre of Electron Microscopy (CNME) in Madrid**, which is managed by the General Foundation of the Complutense University of Madrid (UCM) and by the Vice-Rector of Research and Science Policy at the UCM. It is located at the Chemistry Department of the UCM.

- **The Advanced Microscopy Laboratory (LMA) reports administratively to the University of Zaragoza** through the Institute of Nanoscience of Aragon and is located at the Río Ebro Campus in Zaragoza.

- **The Electron Microscopy Department at the University of Cadiz** is located on the Puerto Real Campus at this university and is part of the Cen-

tral Services of Science and Technology Research at the same university.

- **The Electron Microscopy applied to Materials Unit at the University of Barcelona** is located at the Barcelona Science Park and is part of the Science and Technology Centres (CCiT) at this university.

## INTEGRATED INFRASTRUCTURE FOR ELECTRON MICROSCOPY OF MATERIALS (ELECMI)

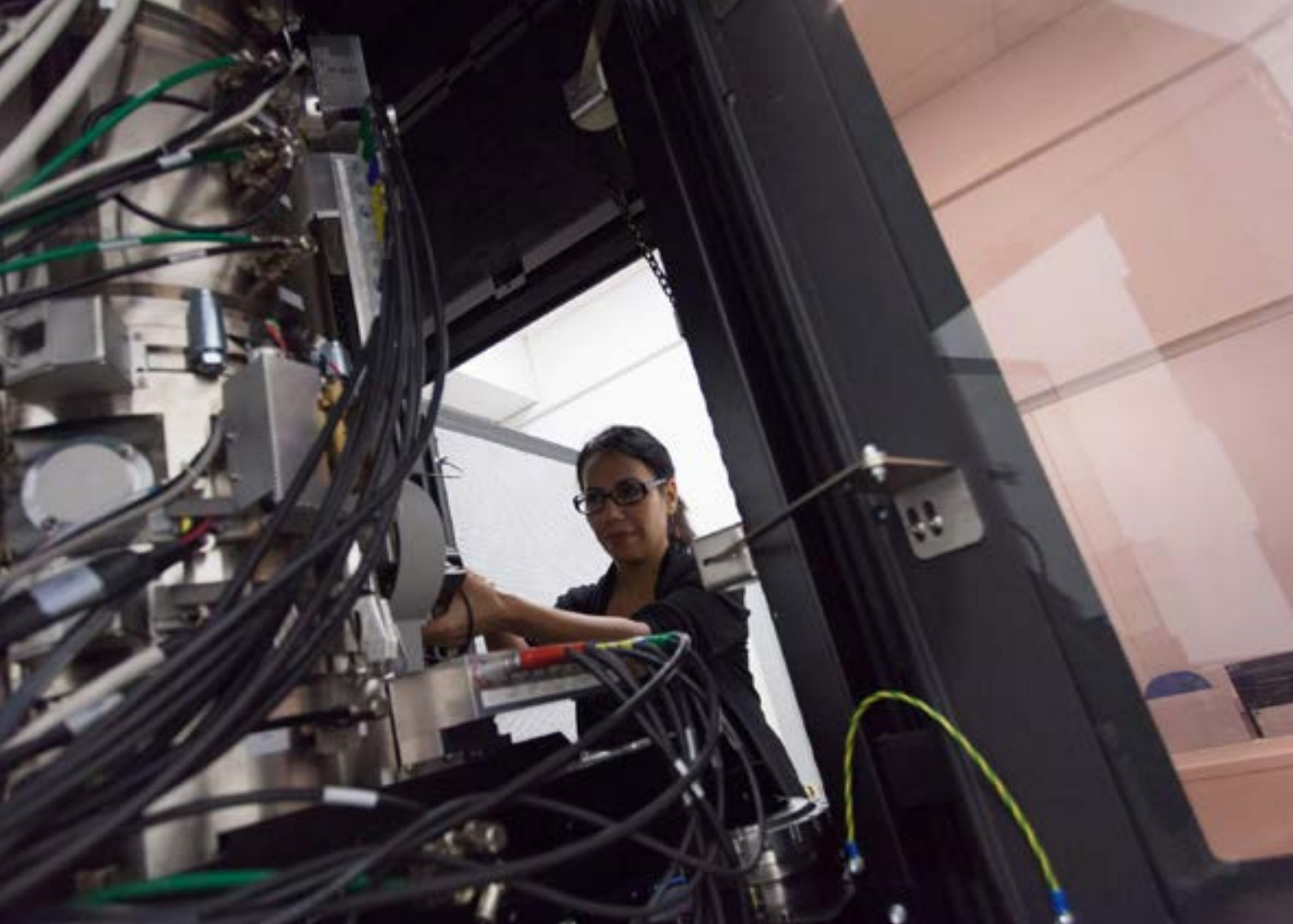
[www.elecmi.es](http://www.elecmi.es)



- ◆ NATIONAL CENTRE OF ELECTRON MICROSCOPY (CNME) IN MADRID
- ◆ ADVANCED MICROSCOPY LABORATORY (LMA) IN ZARAGOZA
- ◆ ELECTRON MICROSCOPY DEPARTMENT AT THE UNIVERSITY OF CÁDIZ
- ◆ ELECTRON MICROSCOPY APPLIED TO MATERIALS UNIT AT THE UNIVERSITY OF BARCELONA







Together, they offer microscopy equipment with exclusive design aspects that make them complementary for applications ranging from crystal chemistry of materials to catalysis, materials for energy, functional materials and communications. Their main goals are development, implementation and availability of the most advanced electron microscopy techniques and methods, allowing for the observation, analysis, characterisation and manipulation of organic and inorganic materials at atomic level. It includes a wide range of transmission and scanning electron microscopes, electron probe microanalyzers and atomic force microscopy devices, including latest-generation, aberration-corrected microscopes.

Two significant developments in the characterisation and use of materials for

molecular sieves can be used to illustrate this. These solids are, microporous sieves which act as filters that let only the access of molecules smaller than the pores. They have a wide range of uses in very different industrial processes. Zeolites have been highly used as sieves for several decades. They are often used in many catalytic processes that enable the speed of chemical reactions to be increased, and have a large impact on industries such as petrochemistry, fine chemicals and separation of gases. Depending on its chemical composition and the topology of its structural pores, different chemical reactions can be carried out. The FEI – Titan Low Base microscope from the LMA has been used to characterise some synthetic zeolites by adding metallic atoms and compounds. These systems are of significant interest in the field of catalysis. They have been

able to identify isolated atoms inside zeolites, which is a huge milestone because these materials are very sensitive to electron beams, making it extremely difficult to observe and analyse them (33).

Meanwhile, the JEM ARM200cF microscope at the CNME has characterised the structure of a new OMS (octahedral molecular sieve) material with electrochromic properties. That is, the colour changes when an electric charge is applied and when it is removed. The material's extreme sensitivity to damage from the electron beam, combined with the need to define the new hexagonal structure of nanometric tungsten oxide ( $WO_3$ ) at an atomic level, means that it is essential to use an electronic transmission microscope with a corrector on the condenser lens that can work at a

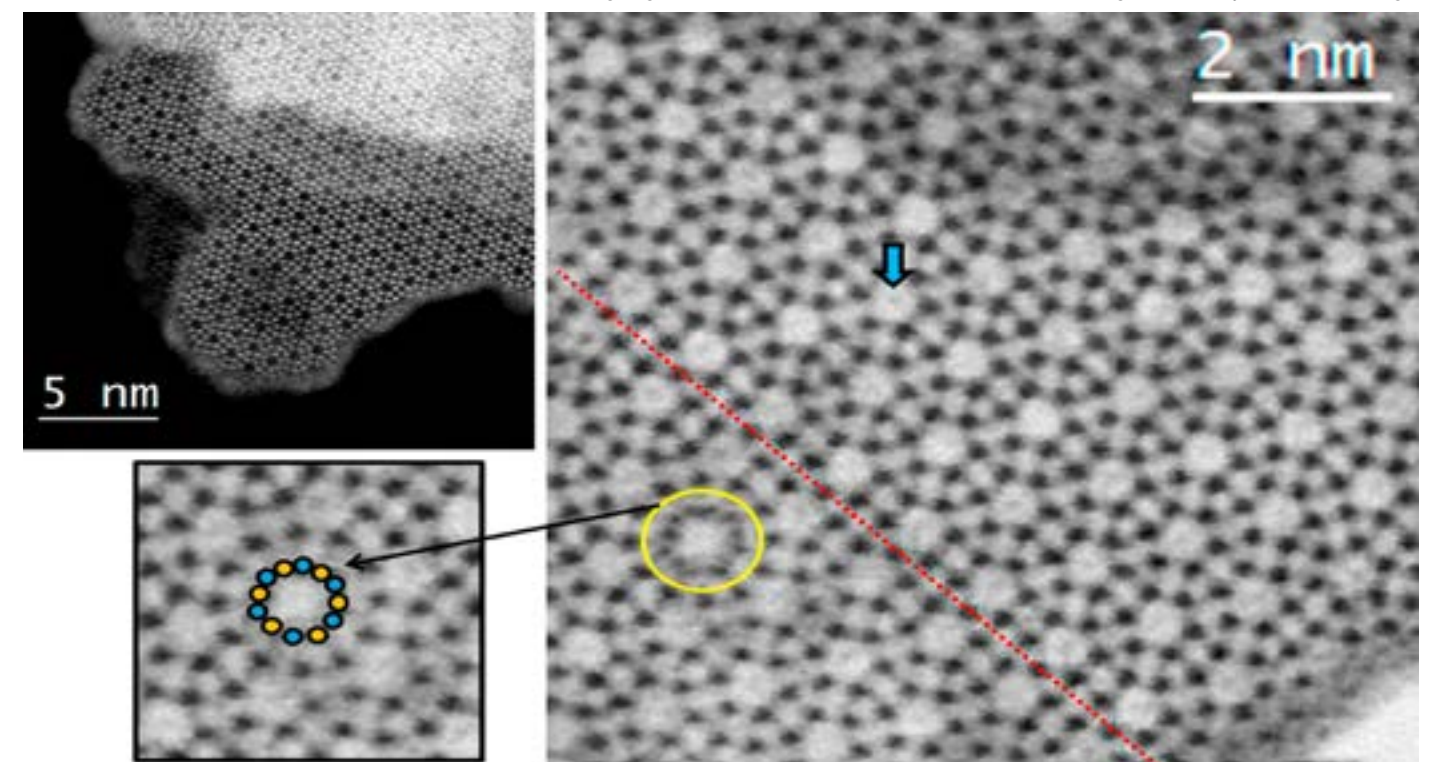


relatively low voltage, similar to the one used in this study. The OMS materials are a type of molecular sieves with greater versatility that extend their use to a wide range of areas such as sensors, energy storage, materials for batteries, environmental recovery, etc. The detailed characterisation of these materials, which means the advanced technologies of these electron microscopy facilities can be applied, opens new fields of use and provides further uses, and makes them more efficient in the existing fields (34).

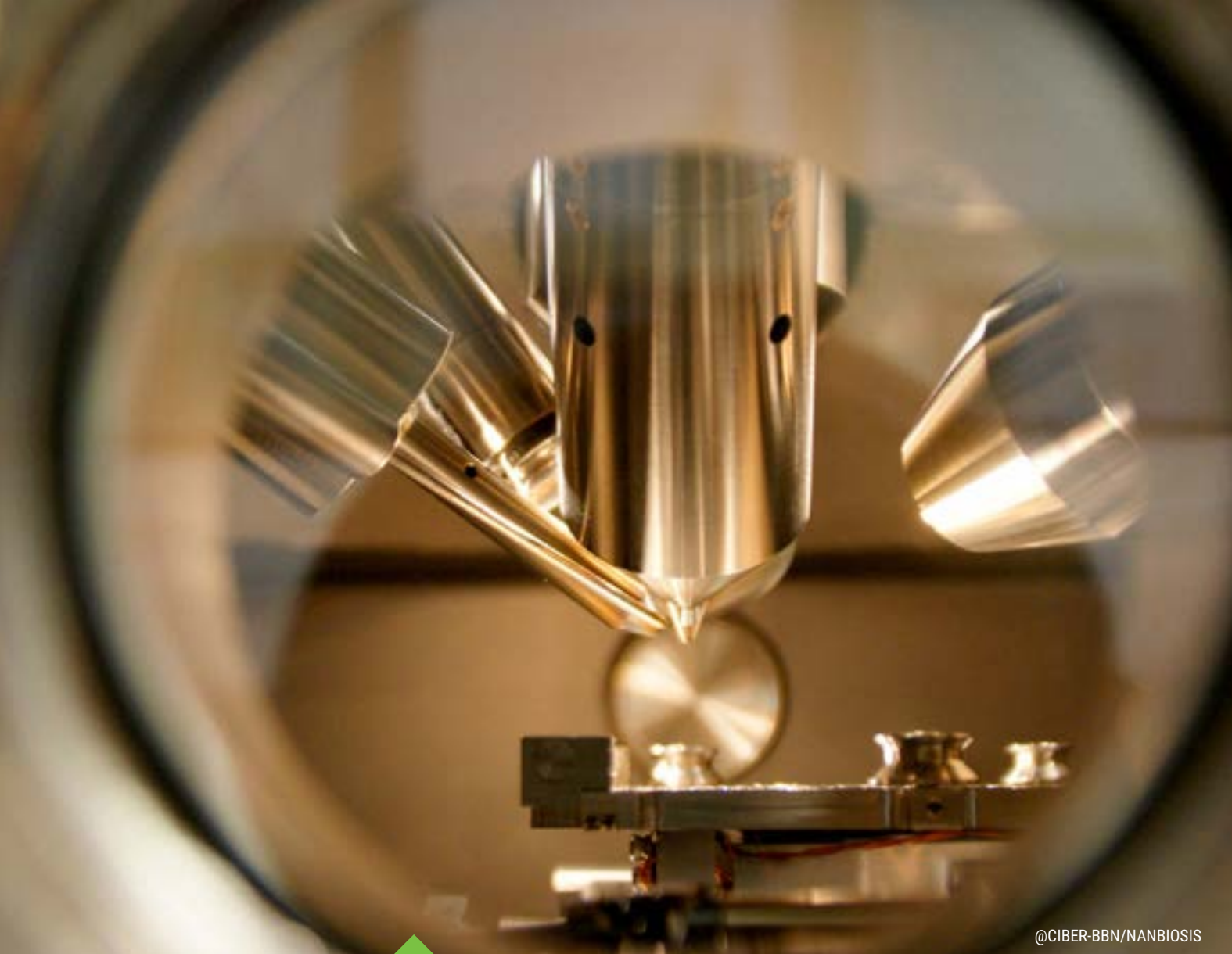
To obtain images with atomic resolution in sensitive systems under the electron beam, it is essential to have an electron microscope, equipped with an aberration corrector able to be aligned at low voltages to minimise the damage caused by the beam and to be equipped with a rapid detection system with a good signal-to-noise ratio. The JEOL GRANDARM 300cFEG microscope at the CNME combines these characteristics and has been used to identify MINT-AQ (rotaxane-like mechanically

interlocked nanotube derivatives) macrocycles around single-wall carbon nanotubes, which has contributed to understanding the catalytic activity of these systems (35).

Top left. Atomically resolved HAADF image of a  $WO_3$  nanoplatelet. Bright dots correspond to W atomic columns. The structure is formed by  $(WO_3)_n$  rings stacked along c axis giving rise to tunnels with an internal diameter of 0.48 nm. Right. Atomically resolved ABF image.







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- ◆ ANDALUSIAN CENTRE FOR NANOMEDICINE AND BIOTECHNOLOGY (BIONAND)



@CCMIJU / NANBIOSIS

**This distributed ICTS is formed by**

- **The Center for Biomedical Research Network (CIBER) in its area of Bioengineering, Biomaterials and Nanomedicine (CIBER-BBN) department.**

CIBER is a consortium belonging to the Carlos III Health Institute (Ministry of Science, Innovation and Universities), which was created in 2006 and divided into 11 thematic research areas. The CIBER-BBN department currently includes 46 research groups from all

around Spain that were selected based on their scientific excellence and whose aim is to conduct translational research in Bioengineering, Biomaterials and Nanomedicine and to transfer the results to the industry.

- **The Jesús Usón Minimally Invasive Surgery Centre (CCMIJU) is a public research centre** whose strategic mission is based on contributing to increasing knowledge and use of the technologies relating to biomedicine and

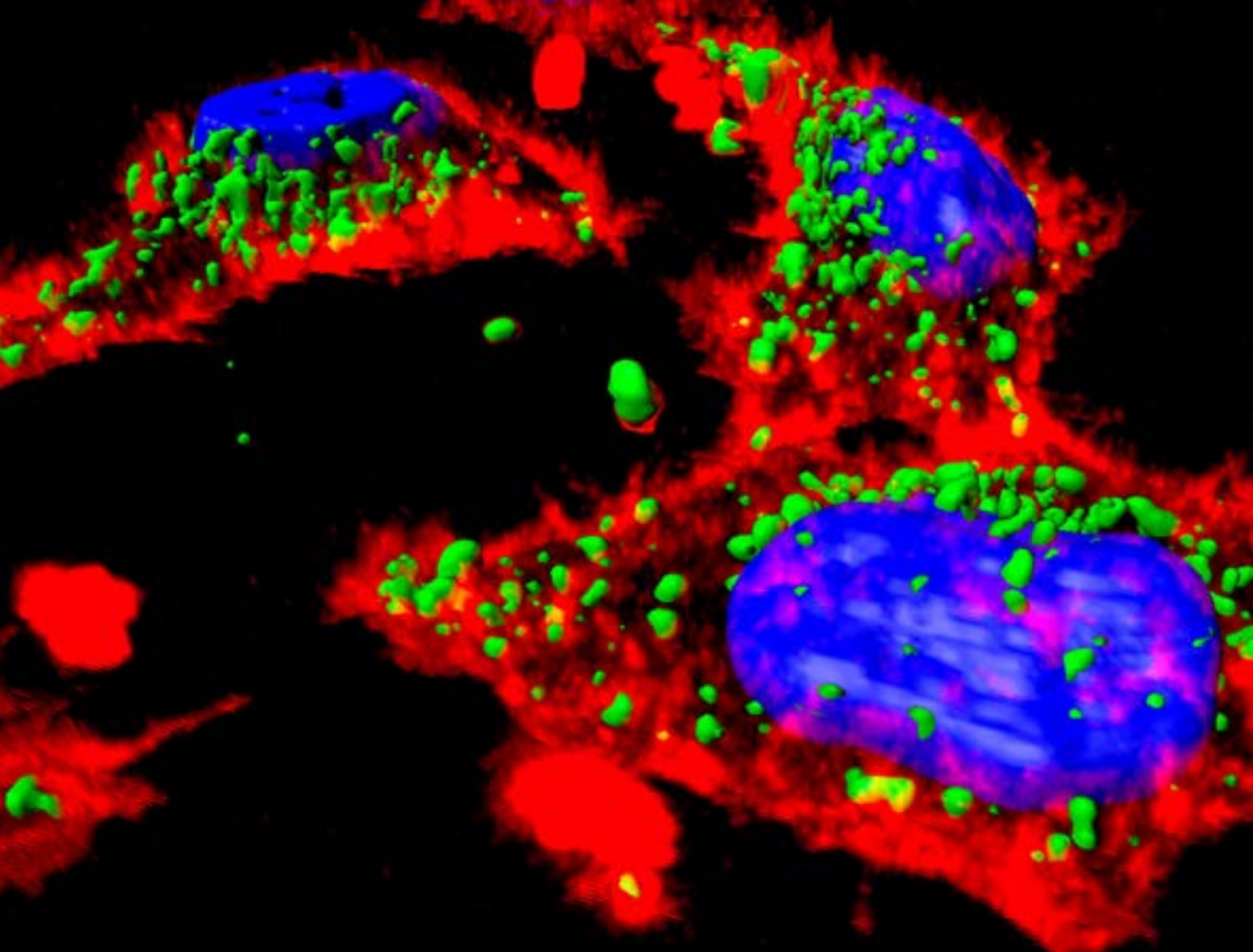
minimally invasive surgery. It is located in Cáceres.

- **BIONAND is a mixed centre that is run by the Andalusia regional government and the University of Malaga.** It was designed as a space for research of excellence in nanomedicine, which will generate new systems to diagnose, prevent and treat illnesses by creating and developing devices, materials and approaches on a nanometric scale.



@CCMIJU / NANBIOSIS





Celular penetrability of a protein-only, nanoscale drug delivery system in cultured target cells. Fluorescence indicate clusters of protein nanoparticles in endosomal compartments (36).

THE NANBIOSIS ICTS is organised into five platforms:

- 1- Production of biomolecules;
- 2- Production of biomaterials and nanomaterials;
- 3- Pre-clinic validation: characterisation of fabrics, biomaterials and surfaces;
- 4- Pre-clinic validation: bioimaging;
- 5- High-performance computing.

These platforms include 27 supplementary and coordinated units located in different centres in Andalusia, Aragon, Catalonia, Extremadura, Madrid and the Basque Country.

Through a one-stop system, NANBIOSIS provides comprehensive solutions that

are tailored to the challenges researchers face in nanomedicine, medical diagnostics and the engineering of fabrics and devices for regenerative medicine, including the design and production of bio/nanomaterials and their nanoconjugates, and the characterisation of these and medical fabrics and devices from a physical-chemical, functional, toxicological and biological perspective and in vivo pre-clinical validation. It provides solutions in several fields of use and its configuration means pioneering multidisciplinary studies can be conducted. Some examples are outlined below.

Regarding characterisation of polymer nanoparticles produced from nanoemulsions as medication drug delivery (a very advantageous method in terms of ver-

satility, robustness, safety and efficiency), the Unit 12 of NANBIOSIS has outlined an original method to prepare nanoparticles of polylactic-co-glycolic acid (PLGA) functionalised with cell-penetrating peptides (CPP), which penetrate the cell membrane and release controlled drug doses into the cells. The smaller size of these nanoparticles compared to the ones provided by other methods represents an advantage for their use *in vivo* (36).

For colorectal cancer, units 1 and 18 have created a medication in partnership with Nanoligent SL., with promising results at the pre-clinical phase, which prevents the emergence of metastasis, eliminates the metastatic cells before they colonize the distant organs, with insignificant toxicity in non-tumour tissues. It is an inno-



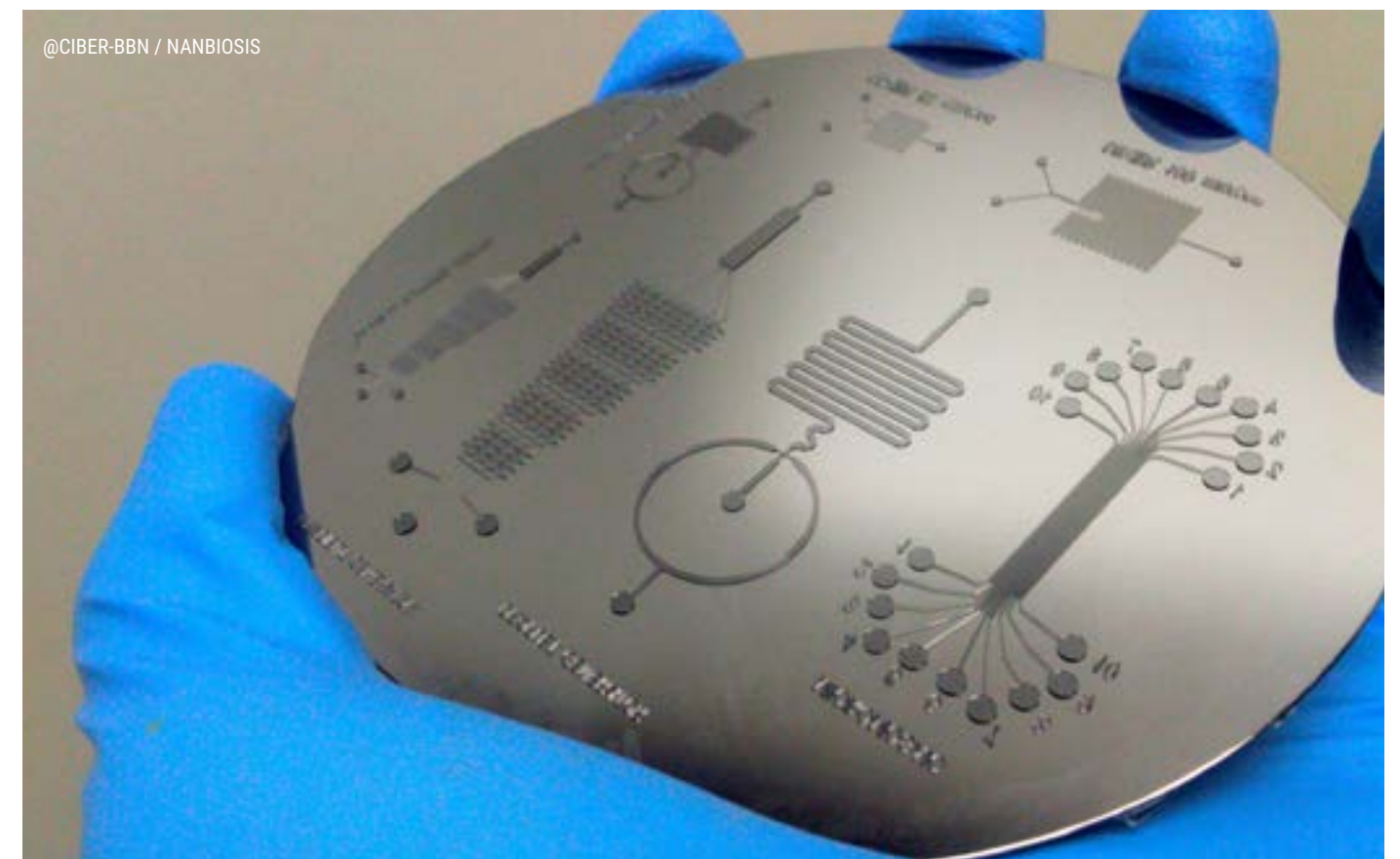
vative medication administration system based on emerging bionanotechnology with protein nanoparticles that selectively deliver lead the therapeutic agent to the tumour cells, therefore avoiding the side effects of chemotherapy. Once this technology is proven to be effective for humans as well, it can be aimed at treating other types of tumours (37).

Unit 4 is working in partnership with research groups and companies on a European project in order to provide a device for the rapid detection of infections. The project has developed a portable and autonomous sensor device based on op-

tical interferometry for the direct detection of bacteria in the plasma of patients with sepsis. The contribution of Unit 4 at NANBIOSIS has proven to be key in generating biofunctionalised chip sensors with specific bioreceptors that follow a microarray pattern. That is, by providing drops whose size is controlled with a high level of precision. The optimised test requires very small sample volume from the patient, offers high sensitivity, and has already been validated with real hospital samples (38).

In the field of surgery and biomaterials, NANBIOSIS Unit 14 (Cell Therapy Unit) has worked together with Unit 21 (Experimen-

tal Operating Rooms), both located at the Jesús Usón Minimally Invasive Surgery Centre in Cáceres, to develop a bioactive surgical mesh to reduce the inflammatory process associated with implanting this type of material. This bioactive mesh is covered with adult stem cells and it has been shown to have a beneficial effect on the biocompatibility of this type of material in animal models. These results have been published in highly influential journals and are protected from possible commercial use by a patent (39).







This infrastructure consists of the following facilities:

**- The Sequencing Platform at the Centro Nacional de Análisis Genómico (Spanish National Centre of Genomic Analysis, CNAG-CRG) and the Proteomics Platform at the Centre for Genomic Regulation (CRG).** The CNAG-CRG has a park of DNA sequencers capable of sequencing over 4,000 gigabases per day, the equivalent of 40 complete human genomes in 24 hours. It is the larg-

est genome centre in Spain and one of the infrastructures with the largest sequencing capacity in Europe. The CRG's Proteomics Platform is located in the Barcelona Biomedical Research Park and is run by the Pompeu Fabra University. It has the most advanced mass spectrometers and provides complete proteomic services through quantitative techniques based on mass spectrometry, which is complemented by genomic services provided by the Sequencing Platform.

**- The Metabolomics Platform at the Centre for Omics Sciences (COS)** belongs to the Rovira y Virgili University and is run by the Eurecat Technology Centre. The integration of multiple technologies for metabolomics and proteomics allows for the use of the most suitable technologies, or a combination of them, in order to determine metabolic profile. The COS uses these technologies in order to increase knowledge on the subject and for innovative applications in health, human and animal nutrition, and the pharmaceutical and environmental industries.



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## INFRASTRUCTURE FOR OMICS TECHNOLOGY (OMICSTECH)

- ◆ SEQUENCING (CNAG-CRG) AND PROTEOMICS (PP-CRG) PLATFORM
- ◆ METABOLOMICS PLATFORM AT THE CENTRE FOR OMICS SCIENCES (COS)





This entire ICTS has the whole range of required technologies to analyse all the elements that make up biological systems, including DNA, RNA, epigenomic marks, proteins, metabolites, and structural elements such as membranes.

The Sequencing Platform at the CNAG-CRG is the only facility in Spain that offers sequencing of nucleic acids from individual cells. This capacity has revealed a new skin aging mechanism by studying the RNA of individual mice skin fibroblasts. These cells lose their cellular identity with age and acquire adipocyte characteristics (fat cells). The discovery opens up new paths for searching for antidotes that counter cell aging and its effects on the organism, therefore having not only long-term cosmetic applications, but

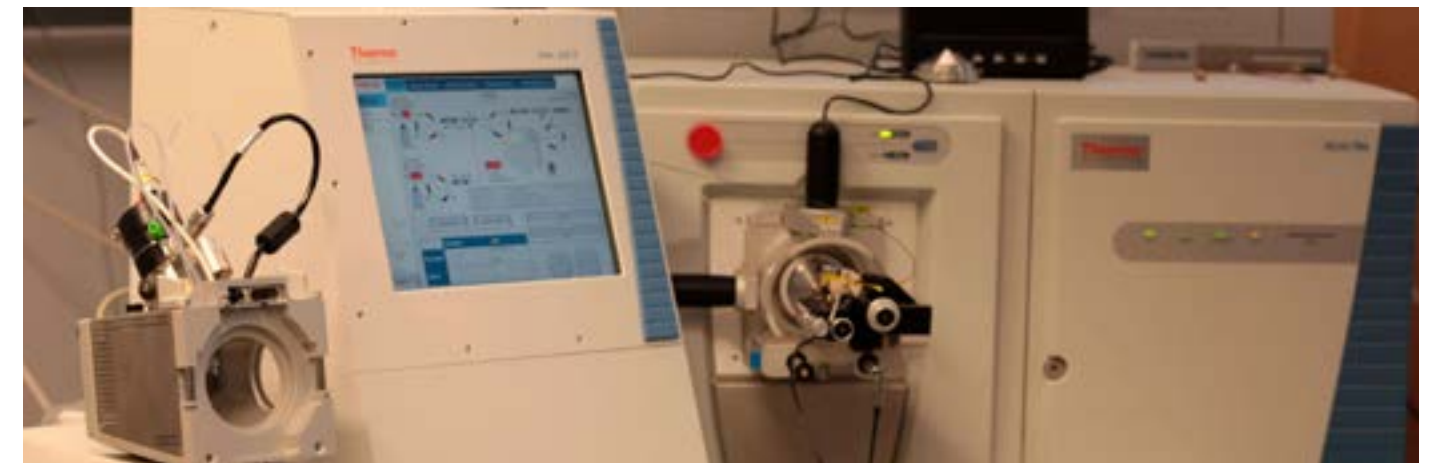
also long-term therapeutic applications in healing processes (40).

Meanwhile, the joint activity of the Sequencing (CNAG-CRG) and Proteomics (PP-CRG) Platforms has evidenced the unicellular origin of cellular differentiation and signalling mechanisms of present-day multicellular organisms. During this study, massive sequencing techniques were applied to *Capsaspora owczarzaki*, the unicellular relative of animals with the largest known genetic repertoire for transcriptional regulation. The use of these techniques enabled thousands of genes and proteins, as well as their modifications, to be studied at the same time.

Using the acquired data, the researchers discovered crucial differences among

the unicellular and collective states of the *Capsaspora* organism in terms of genetic regulation and in the quantities of certain proteins and their associated modifications. These observations established the unicellular origin of many cellular differentiation and signalling mechanisms currently located in multicellular beings such as animals. This research is important to elucidate the origin of multicellular organisms and to understand how ancestral mechanisms established the functioning foundations of present-day animals (41, 42).

In the field of metabolomics, and in the context of the "GCAT/Genomas por la Vida" Project, the COS characterised the metabolites in 5,000 samples of human plasma to identify metabolic markers to



be used in global association studies of metabolome, and to identify genetically determined endophenotypes. Methodologies that ensured the homogeneity and comparability of the data throughout the study, and with future data, were applied to maintain continuity.

The viability of metabolomics for discovering biomarkers is supported by the

hypothesis that the metabolites are important actors in biological systems, and that illnesses cause the interruption or malfunction of biochemical pathways. The systematic analysis of metabolites with low molecular weight in biological samples has become an important tool in clinical research and diagnosis. In this project, metabolomics is applied to the discovery and identification of

altered metabolic pathways, providing a holistic approach with the guarantee of clinically improving diagnostics, understanding the underlying mechanisms of the illnesses, helping identify the patients at risk of illness and predicting the response to specific treatments.







@CEHIPAR\_INTA

## MARITIME AGGREGATED RESEARCH HYDRAULIC INFRASTRUCTURES (MARHIS)

[www.ictsmarhis.com/en](http://www.ictsmarhis.com/en)



- ◆ CANTABRIA COASTAL AND OCEAN BASIN (GTIM/CCOB)
- ◆ INTEGRATED COASTAL INFRASTRUCTURES FOR EXPERIMENTATION AND MODELLING (ICIEM)
- ◆ EL PARDO HYDRODYNAMICS EXPERIENCES CENTRE (CEHIPAR)
- ◆ BISCAY MARINE ENERGY PLATFORM (BiMEP)
- ◆ TEST SITE OF THE OCEANIC PLATFORM OF THE CANARY ISLANDS (PLOCAN)

MARHIS (Maritime Aggregated Research Hydraulic Infrastructures) is a distributed ICTS with the goal of increasing the competitiveness and efficiency of the Spanish ICTS in the area of hydraulic maritime engineering (coastal, ports, and offshore), offering its infrastructures and technological services in a coordinated manner. It consists of:

- **Cantabria Coastal and Ocean Basin (GTIM/CCOB), located in the Scientific and Technological Park of Cantabria (PCTCAN),** Santander, and is managed by the Environmental Hydraulics Foundation.
- **Integrated Coastal Infrastructures for Experimentation and Modelling (ICIEM),** managed by the Maritime Engineering Laboratory, a specific research centre of the Universidad Politécnica de Cataluña Barcelona Tech (LIM/UPC) and located at dife-

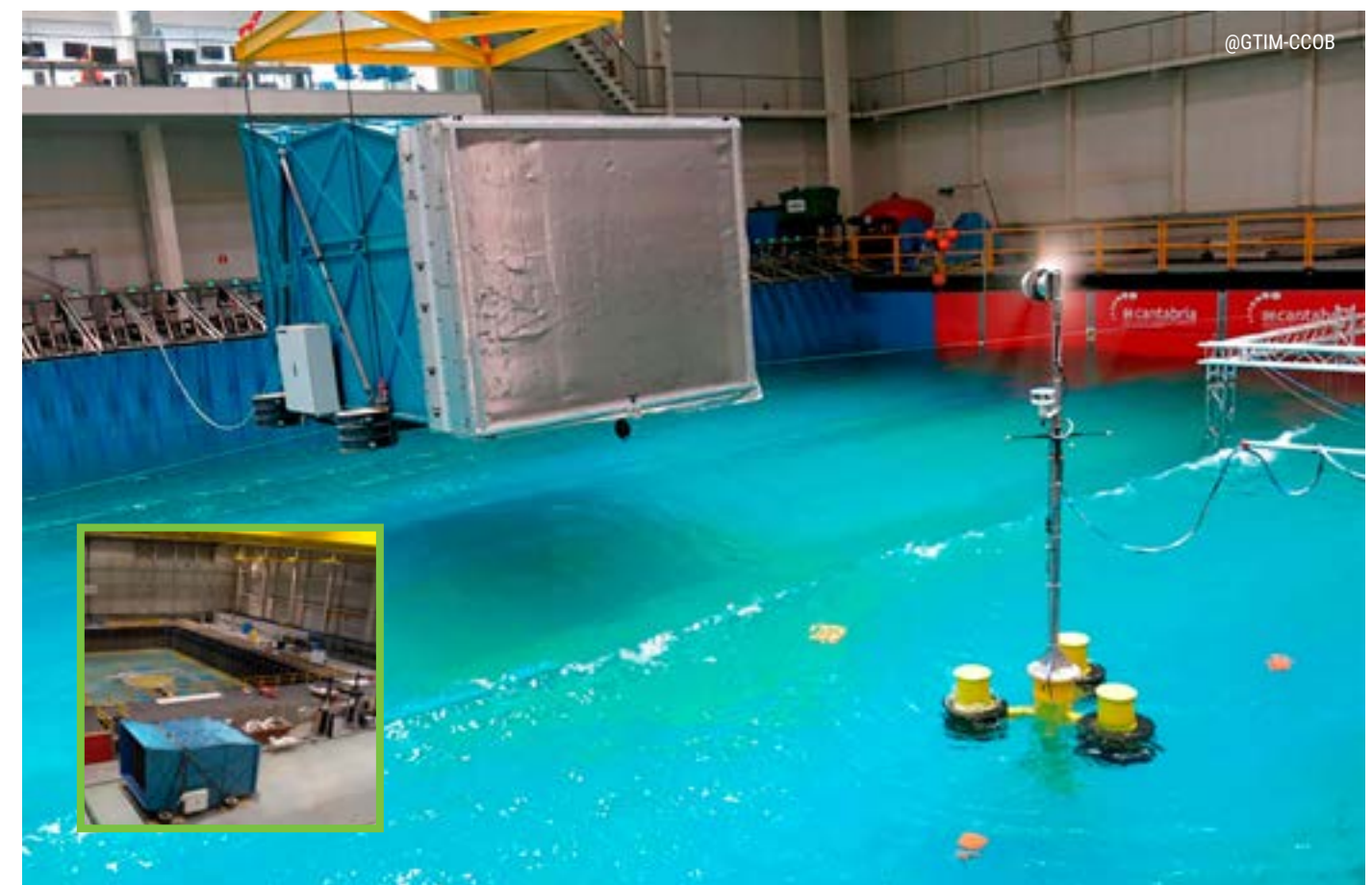
rent sites along the Barcelona coastline.

- **El Pardo Hydrodynamics Experiences Centre (CEHIPAR),** belongs to the Spanish National Institute of Aerospace Technology (INTA) and is located in El Pardo (Madrid).
- **Biscay Marine Energy Platform (BiMEP),** a public company of Ente Vasco de la Energia (EVE) and the Institute for the Diversification and Saving of Energy (IDAE), is located offshore and has a limited sailing area of 5.3 km<sup>2</sup> in the sea off the coast of Arminza.
- **Test site of the Oceanic Platform of the Canary Islands (PLOCAN),** managed by the PLOCAN Consortium (equally co-financed by the Spanish government and the Canary Islands regional government), and located

offshore in the town of Telde (north-east of the island of Gran Canaria) in an area of 23km<sup>2</sup> reserved for technical scientific experimentation.

Among the different European policies designed to tackle climate change, it is worth mentioning those aimed at substantially reducing CO<sub>2</sub> emissions, which are also accompanied by policies relating to the Blue Economy. In this respect, facilities such as MARHIS are fundamental in supporting and enabling the development of technological innovation together electricity through clean energy.

The capacity to combine wave, current and wind conditions is something that can only be reproduced in Spain in a 3D tank at GTIM CCOB. As part of the European project Marinet II, these facilities have validated and characterised the Starfloat device (Oceanflow Energy Limited), a wind generator on a bed of



@GTIM-CCOB





@PLOCAN

fans for harnessing offshore wind. The possibility of creating controlled conditions that would support its real operation, while replicating the depth conditions and mooring systems that relate to its floating nature, facilitate and accelerate the development of this technology.

Meanwhile, CEHIPAR has tested another technology aimed at using the ocean currents in areas with high-speed currents at great depths. In general, the validation of this type of real prototype is impossible because of the associated costs. Therefore, it is essential to have facilities that can carry out tests on a smaller scale to optimise the different configuration options of the design, ensuring viability both in terms of energy

generation and the stability of the structure positioned at great depths and subjected to high-speed currents.

Offshore, the objective of the platforms proposed by PLOCAN and BiMEP is to allow technology developers in the field of renewable marine energy to install and test their equipment, systems and subsystems. In this respect, it is part of the ELISA/ELICAN project, executed by PLOCAN, which has developed an innovative telescopic tower system on a concrete base. It is designed to be transferred by floating to its mooring spot, together with the wind turbine previously mounted at the port. This will enable wind turbines to be installed at sea with a lower cost and with fewer risks. The

ELISA/ELICAN project is funded by the European Union within the Horizon 2020 programme. Similarly, BiMEP has tested MARMOK-A5, a wave energy collection device which is built to scale but in a low-power format. It is a floating wave power converter that uses oscillating water column technology to use the energy from waves to create electricity, which is then delivered the grid. Together with the device itself, a series of innovations related to generation, mooring and control systems have been tested within the European project OPERA. In addition to the technical innovations, this innovative technology contributes to power generation through clean energies, thereby reducing the use of fossil fuels in the electricity system and im-



Twin propeller test to study de velocity field generated over a rigid and mobile bottom (@iCIEM).

proving environmental sustainability in terms of impact on marine life and carbon footprint.

In another field of application, iCIEM has assessed the erosion resulting from ferry propulsion systems while they

are mooring and unmooring at a port. This has enabled the iCIEM to characterise the erosion process with the aim of studying and finding solutions for protecting port facilities. The LaBassA facility has conducted a 1:25 scale prototype study for this type of physical

phenomenon, which can be replicated at very few facilities. By simulating and monitoring the propulsion of ferries to forecast erosion at ports, the field of knowledge has expanded to include the use of double helix propulsion, which did not previously exist.



@BiMEP





## NETWORK OF HIGH BIOSAFETY LEVEL LABORATORIES (RLASB)

www.rlasb.es



This network includes the High Biosafety Level Laboratories that are open to the national and international scientific communities and which, due to their sizes and/or characteristics of the facilities, provide a unique opportunity for experimental studies otherwise not feasible at conventional centres. The network consists of two facilities:

- **The High Biosafety Laboratory at the Animal Health Research Centre (CISA)**, located in Valdeolmos (Madrid). It belongs to the Spanish National Institute for Agricultural and Food Research and Technology (INIA), a public research body of the Ministry of Science, Innovation and Universities. It occupies 10,824 m<sup>2</sup>, with 40 BSL-3 laboratories (OMS) and two BSL-4 laboratories (OIE). The BSL-4 laboratories (OIE) are unique in Spain and are designed

for studies using infectious agents that could affect humans. It has 19 experimental boxes in the animal facility and in auxiliary areas, four of which are BSL-4 (OIE), designed to host animals ranging from fish to large animals. It is the only Spanish facility authorised to use the foot-and-mouth virus in vivo. It is a Reference contact regarding Biosafety for the FAO.

- **High Biosafety Laboratory of the Centre de Recerca en Sanitat Animal (CReSA)**, located on the campus of the Universitat Autònoma de Barcelona (UAB). The centre belongs to the Institute of Agrifood Research and Technology (IRTA), a public company of the regional Government of Catalonia, within the regional Ministry of Agriculture, Livestock, Fisheries and Food. It has six BSL-3 laboratories and 12 experimental rooms in the animal facility with a total area of 1,150 m<sup>2</sup>, both for farm and wild animals, and small laboratory animals.

The research of this ICTS is focused in diseases that have a health and economic impact, both on animal health and public health (zoonotic diseases). Both nodes are

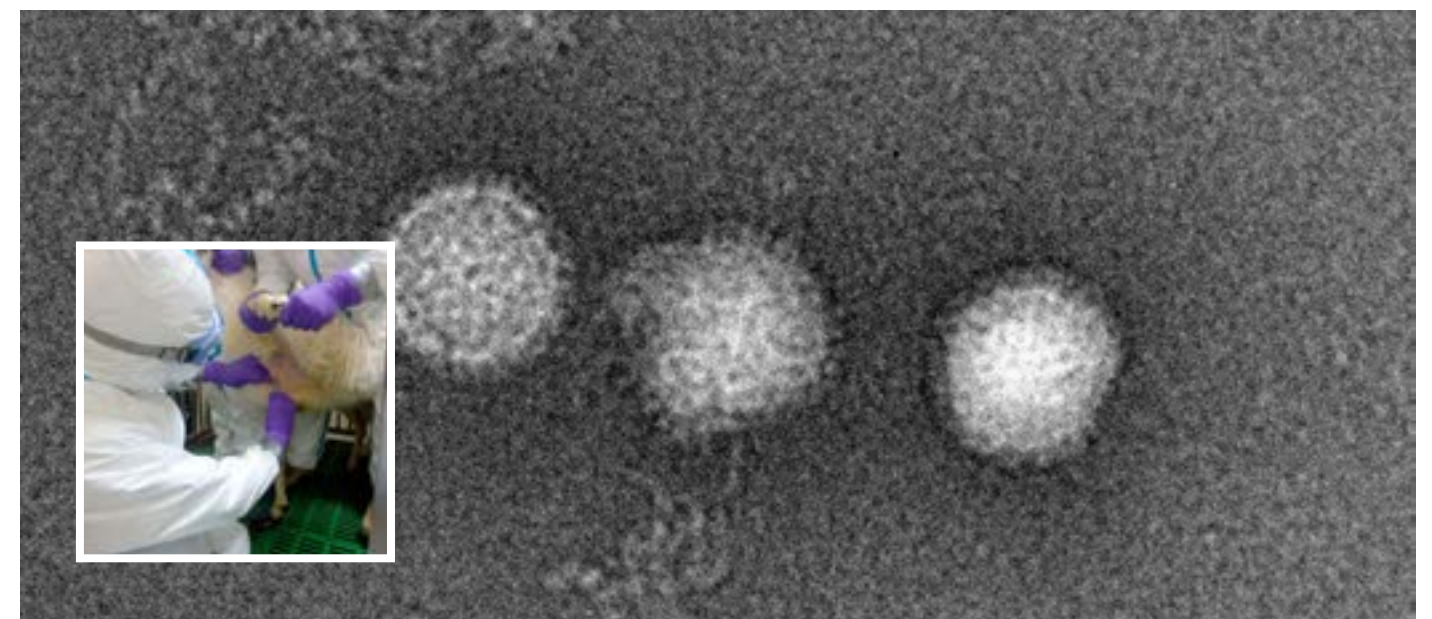
part of the scientific-technical Biological Alert Laboratories Network (RE-LAB), which provides operational support to the National System for Conducting Crisis Situations for dealing with threats from dangerous biological agents. They actively participate in improving the knowledge and technological development of diagnostic systems and control of infectious and exotic diseases from livestock and wildlife in Spain.

RLASB conducts highly specialised studies that would not be possible at other facilities. One of these studies has provided information about Rift Valley Fever, an African disease that is totally unknown in Europe, and which affects ovine, bovine and camelid livestock. The virus causing this disease is transmitted between animals, and also between animals and humans, through infected mosquito bites, meaning it is also considered a zoonotic disease. In some cases, the infection can be lethal in both animals and humans. The arrival of Rift Valley Fever in Spain could have grave consequences for both human and animal health as it could pose a risk to the economy of animal production and the agrifood industry. It has been forecasted that the virus could spread

endemically across the peninsula because there are some autochthonous mosquito species that can transmit the virus to their offspring, therefore spreading the disease.

The high biosafety laboratories at the RLASB have conducted experiments to replicate the infection cycle of the Rift Valley Fever virus in sheep. These experiments have obtained clinical, virological and immunological data about the consequences of this viral infection in these animals, and have confirmed that the autochthonous animals are susceptible to infection from the virus. After establishing the infection model, different studies were conducted into the effectiveness of experimental vaccinations, both in laboratory animals (mice) and sheep. Specific serums were also collected and helped to prepare and validate diagnostic tests of the disease. Finally, under experimental conditions, it was shown that some species of mosquito in Spain, such as the common mosquito (*Culex pipiens*) and the tiger mosquito (*Aedes albopictus*), can transmit the virus and contribute to spreading the disease (43).

Inoculation and Rift Valley fever virus image.







@LRB



@LRB

**The Barcelona Nuclear Magnetic Resonance Laboratory (LRB)** is located in the Barcelona Science Park and is part of the Science and Technology Centres (CCIT) of the University of Barcelona. The LRB is located on a 722 m<sup>2</sup> site especially designed to host high-field Nuclear Magnetic Resonance (NMR) spectrometers. It is vibration-free and has precise

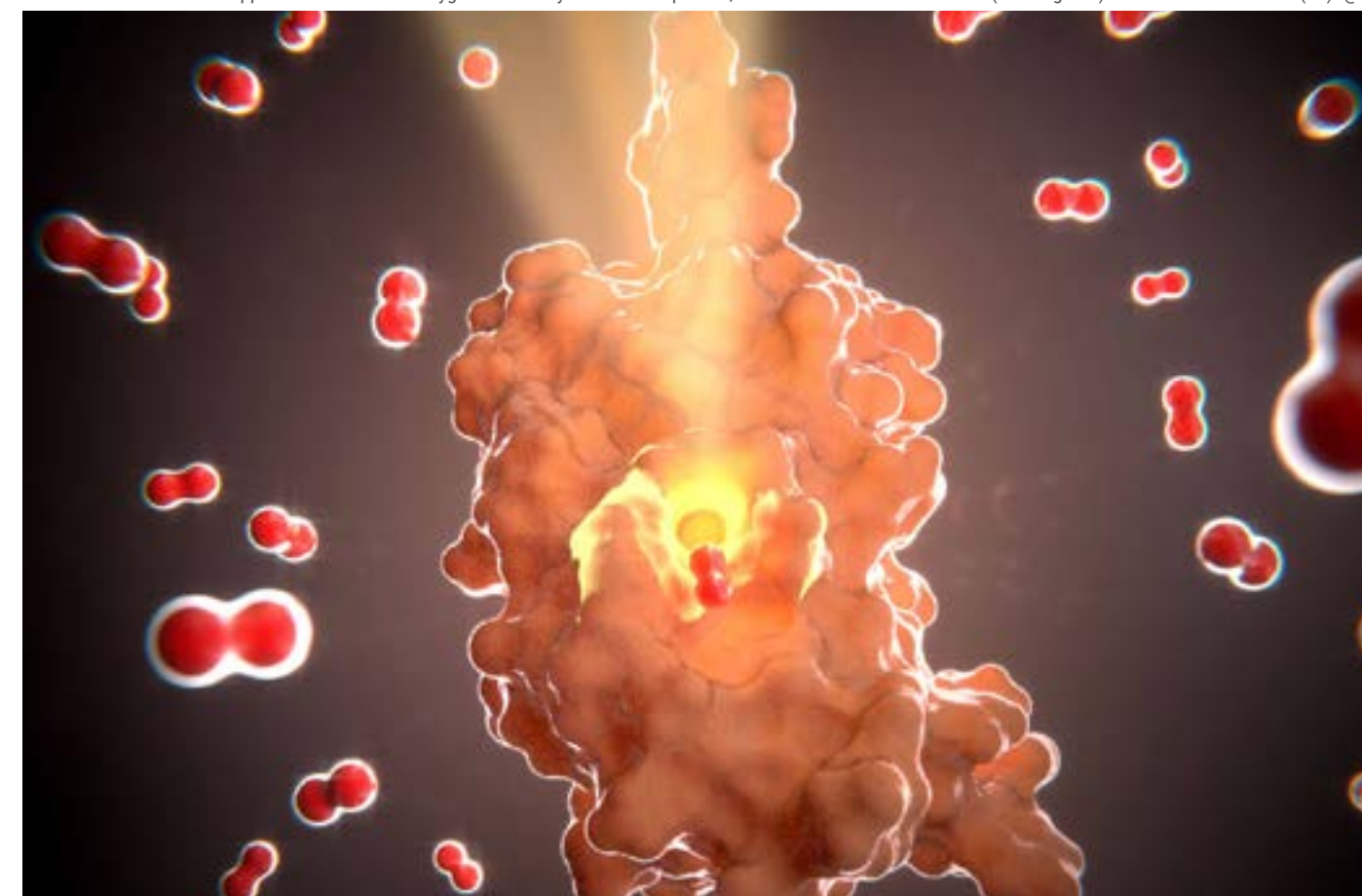
thermoregulation to ensure high stability and low magnetic interference. The facility became operational in 2000.

**The Manuel Rico Nuclear Magnetic Resonance Laboratory (LMR)** at the Rocasolano Institute of Physical Chemistry of the Spanish National Research Council (CSIC), is located in Madrid. The first Nuclear

Magnetic Resonance (NMR) spectrometer in Spain was installed in this center in 1964.

**The Basque Country Nuclear Magnetic Resonance Laboratory (LRE)** of the Center for Cooperative Research in Biosciences (CIC-bioGUNE) is located at the Bizkaia Science and Technology Park in Derio and opened in 2005.

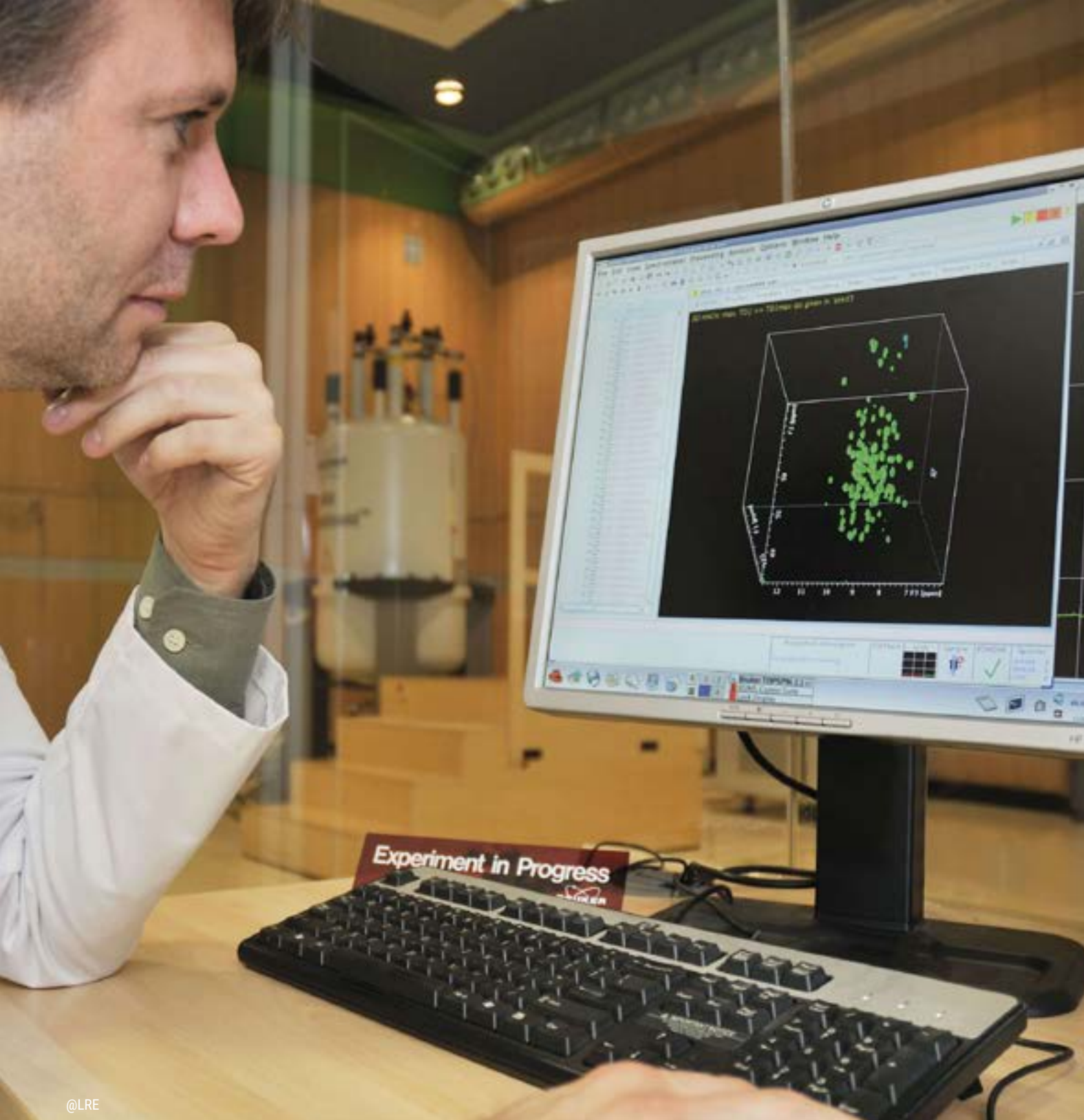
Artist's view of the approach of molecular oxygen to a cavity in the TomB protein, where it is activated to oxidize (and degrade) the Hha bacterial toxin (44). @UB



## BIOMOLECULAR NUCLEAR MAGNETIC RESONANCE LABORATORY NETWORK (R-LRB)

- ◆ BARCELONA NUCLEAR MAGNETIC RESONANCE LABORATORY (LRB)
- ◆ MANUEL RICO NUCLEAR MAGNETIC RESONANCE LABORATORY (LMR)
- ◆ BASQUE COUNTRY NUCLEAR MAGNETIC RESONANCE LABORATORY (LRE)





@LRE

This ICTS combines the facilities with the highest-field NMR equipment in Spain, and is open to the entire scientific, technological and industrial community. It has an extensive set of instruments with fields between 18.8–11.7 Tesla, which correspond to proton frequencies between 800 and 500 MHz.

NMR is used for studies in a large number of fields, such as the structure and

dynamics of biomolecules, functional biology (NMR *in vivo*), identification and optimization of pharmaceuticals in pharmaceutical research, including drug delivery, structural identification in organic and inorganic chemistry, food technology, and new materials.

An example of these activities is one of the projects carried out in the LRB regarding the development of new thera-

pies for antitumour treatment. One of the distinguishing markers of cancer is the overproduction of growth factors such as EGF (Epidermal Growth Factor). Despite the clinical success of therapies aimed at the EGF receptor, its long-term effectiveness is compromised by the emergence of mutations that are resistant to the medication. To address this problem, a special class of antibodies named “nanobodies” have been generated. These are more sta-



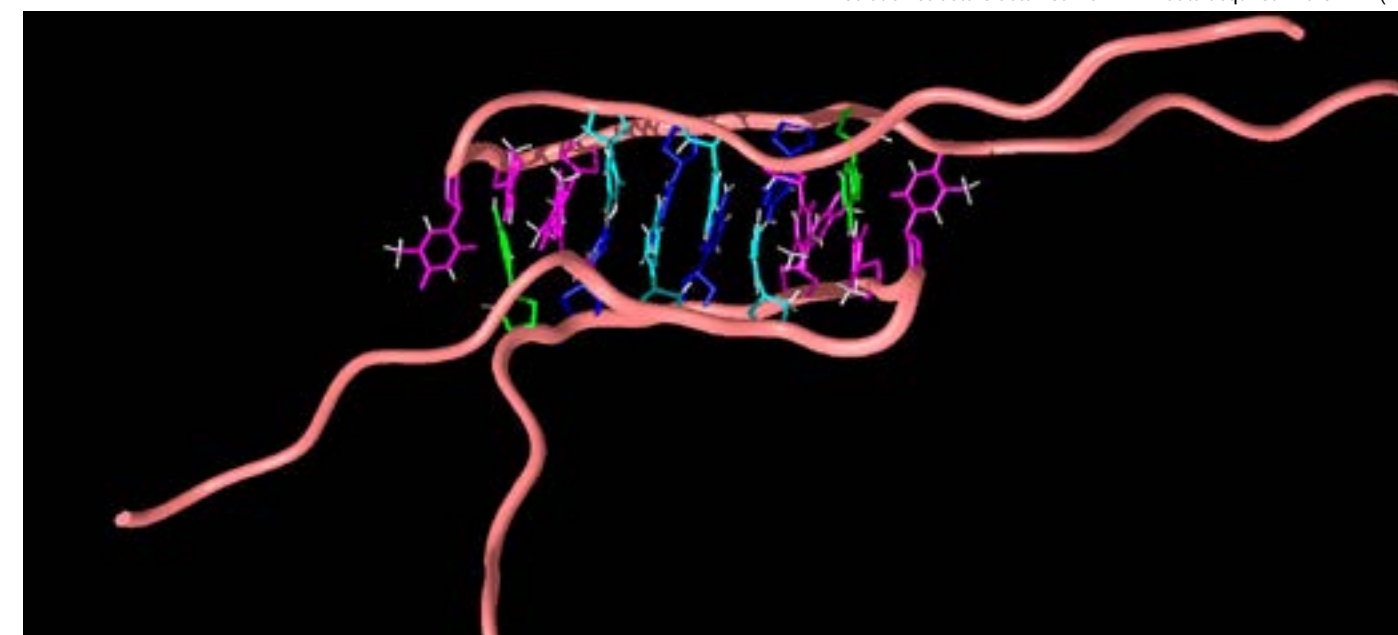
@LMR

ble and easy to obtain than the traditional ones, so they are expected to be widely used in the future of cancer treatment. For the first time, this study describes the action mechanism of two nanobodies capable of joining with the EGF and blocking this protein's union with its receptor, thus explaining the interaction mechanism of every antibody with its target protein (EGF) and also managing to discover the area of the protein recognised by the antibody. This result opens the way for a totally new cancer treatment because the EGF protein is responsible for spreading malignant cells in a large variety of tumours (44).

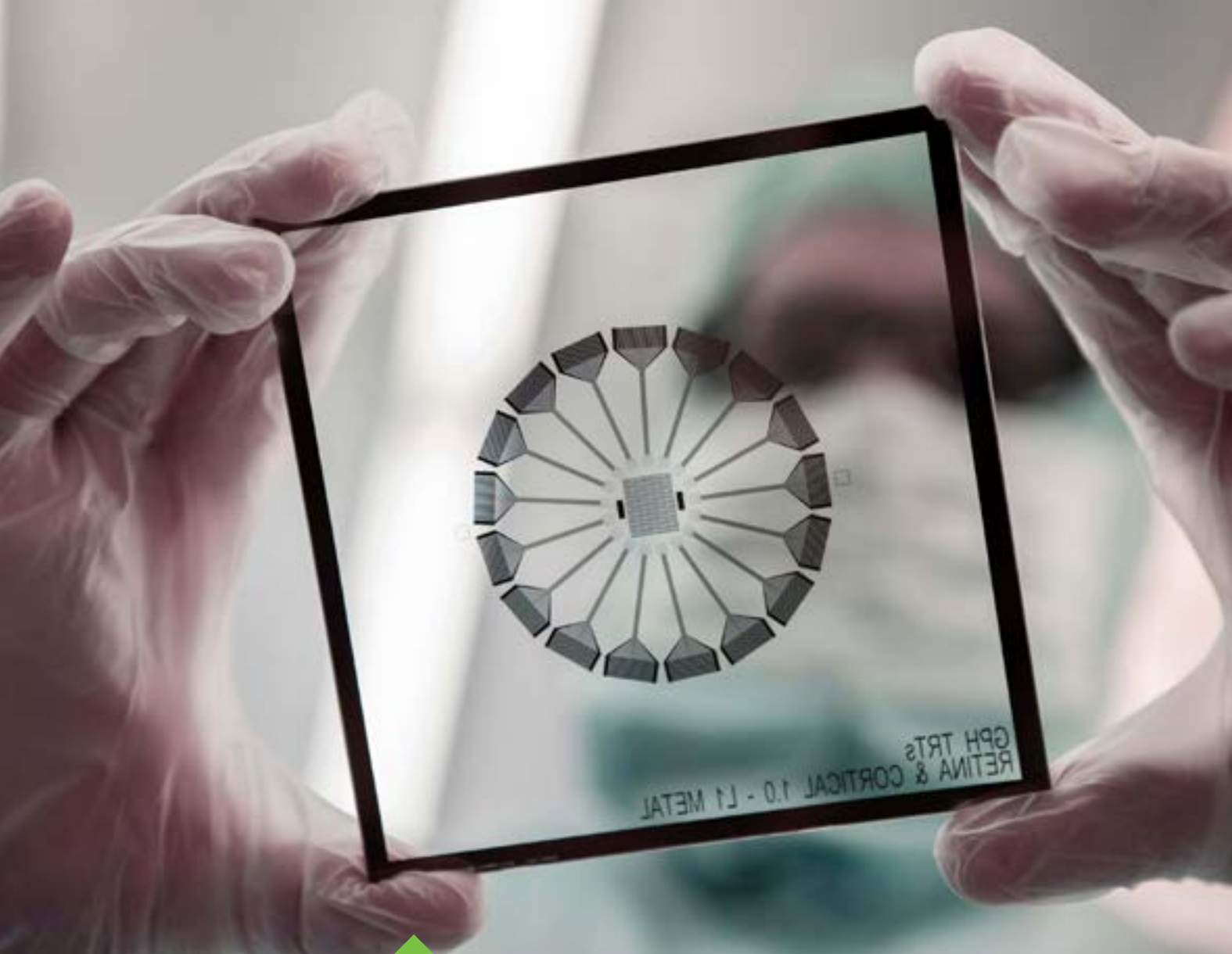
Another achievement in the field of biomedicine was the structural and functional characterisation of a bacterial protein that opens the way for a new attack strategy for resistance to antibiotics. Biofilms are communities of bacteria attached to solid substrates and protected from the environment, which render them resistant to antibiotics. Biofilms attached to catheters or prosthetic implants can represent an important health threat. Eventually, the bacteria that form these resistant structures escape and form new colonies, thus spreading the infection. Controlling this process is

crucial and involves the bacterial toxin-antitoxin system that is based on generating a toxic molecule and its antidote at the same time. Using the latest advances in NMR and, in particular, paramagnetic probes, it has been possible to demonstrate the temporary interaction between the toxin and the antitoxin of this system, therefore providing data for developing a new strategy to eliminate the bacterial colonies of biofilms using their own toxin. This would avoid resistance to externally-administered antibiotics (45).

Non-canonical DNA structure (i-motif) formed by human centromeric sequences. Three-dimensional solution structure obtained from NMR data acquired in the LMR (46).







## MICRO AND NANOFABRICATION CLEANROOMS NETWORK (MICRONANOFABS)

[www.micronanofabs.org](http://www.micronanofabs.org)



- ◆ INTEGRATED MICRO AND NANOFABRICATION CLEANROOM OF THE NATIONAL MICROELECTRONICS CENTER (SBCNM)
- ◆ CENTRE FOR TECHNOLOGY OF THE INSTITUTE OF OPTOELECTRONICS SYSTEMS AND MICROTECHNOLOGY (CT-ISOM)
- ◆ MICRO AND NANOFABRICATION INFRASTRUCTURE OF THE NANOPHOTONICS TECHNOLOGY CENTER IN VALENCIA (INF-NTC)

This distributed ICTS offers more than 2,000 m<sup>2</sup> of cleanrooms (types 10-100-1,000) to the scientific community and industry, along with associated laboratories for the encapsulation and characterisation of systems and devices. It consists of:

- **Integrated Micro and Nanofabrication Cleanroom of the National Microelectronics Center (SBCNM)**, belonging to the Spanish National Research Council (CSIC) and managed as part of the Barcelona Microelectronics Institute, located in Barcelona.
- **Centre for Technology of the Institute of Optoelectronics Systems and Microtechnology (CT-ISOM)**, University Research Institute of the Technical University of Madrid (UPM), located in the School of Telecommunications Engineering in Madrid.

- **Micro and Nanofabrication Infrastructure of the Nanophotonics Technology Center in Valencia (INF-NTC)**, which belongs to the Universitat Politècnica de València (UPV) and is located on the Vera Campus.

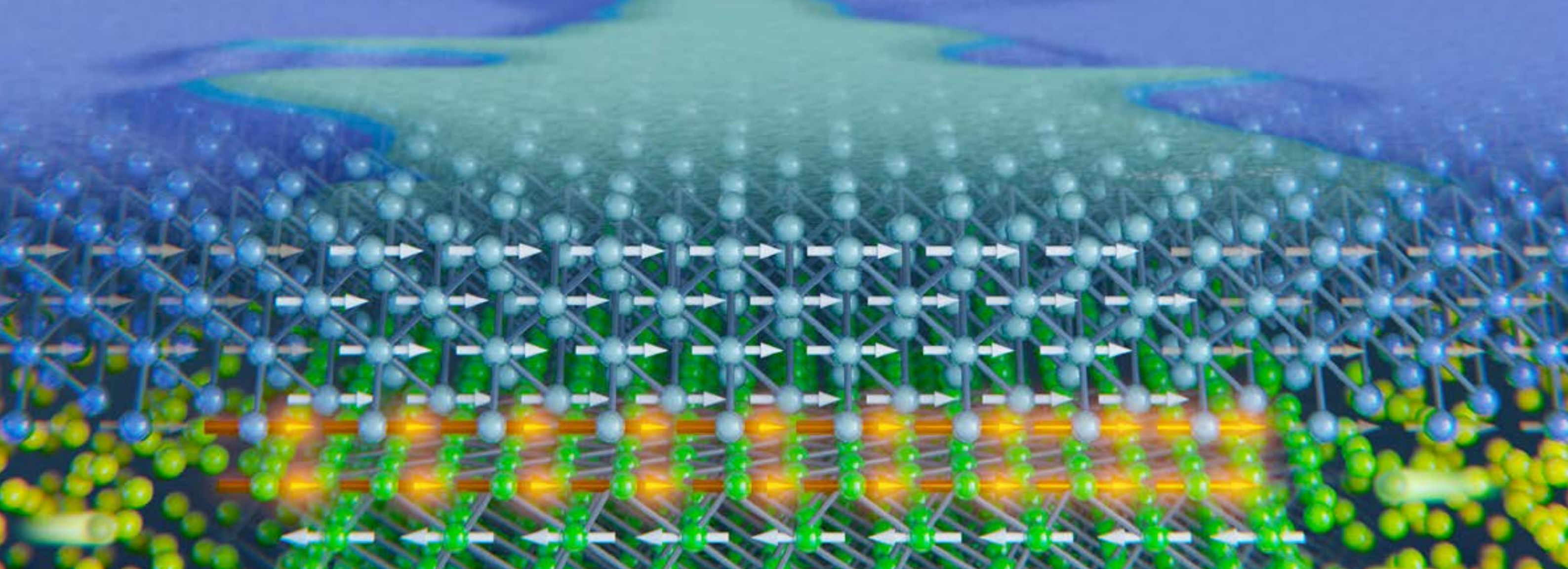
The three facilities are coordinated to provide services in the fields of Micro and Nanoelectronics, Optoelectronics, and Nanophotonics. They develop and apply innovative technologies in almost all scientific areas, such as health, biomedicine, environment, food, energy, mobility, security, communications, consumer electronics, etc. To illustrate this, some of the most significant technologies are listed below.

The SBCNM manufactured the protection diodes for the photovoltaic cells of the solar panels on the probes of the BEPI-Colombo mission, led by the European Space Agency (ESA) in col-

laboration with the Japan Aerospace Exploration Agency (JAXA). Over the course of 45 minutes, these panels will experience very high temperatures (250°C) when it is daytime on Mercury, and very low temperatures (160°C) when it is on the dark side of the planet. These temperature requirements made it necessary to use advanced power component manufacturing technology for extreme temperatures based on silicon carbide (SiC), a new-generation material capable of withstanding very extreme environments conditions. These components do not currently have an equivalent and are almost unique at a global World and European level. They have future applications in electronic systems of electric vehicles, aeroplane jets, wind turbines and train and underground rail braking systems, where the electronics are submitted to very demanding conditions in terms of temperature and power.







Artist's view of antiferromagnetic material converting amorphous form ( yellow balls) into crystalline form (green balls) spontaneously and at room temperature, establishing an exchange interaction (orange arrows) with the ferromagnetic material (blue balls) (47).

In the field of communications, the CT-ISOM has discovered a new physical mechanism for generating magnetic surface interaction, known as "Exchange Bias". This is key for the operation of a large percentage of modern magnetic devices, including hard

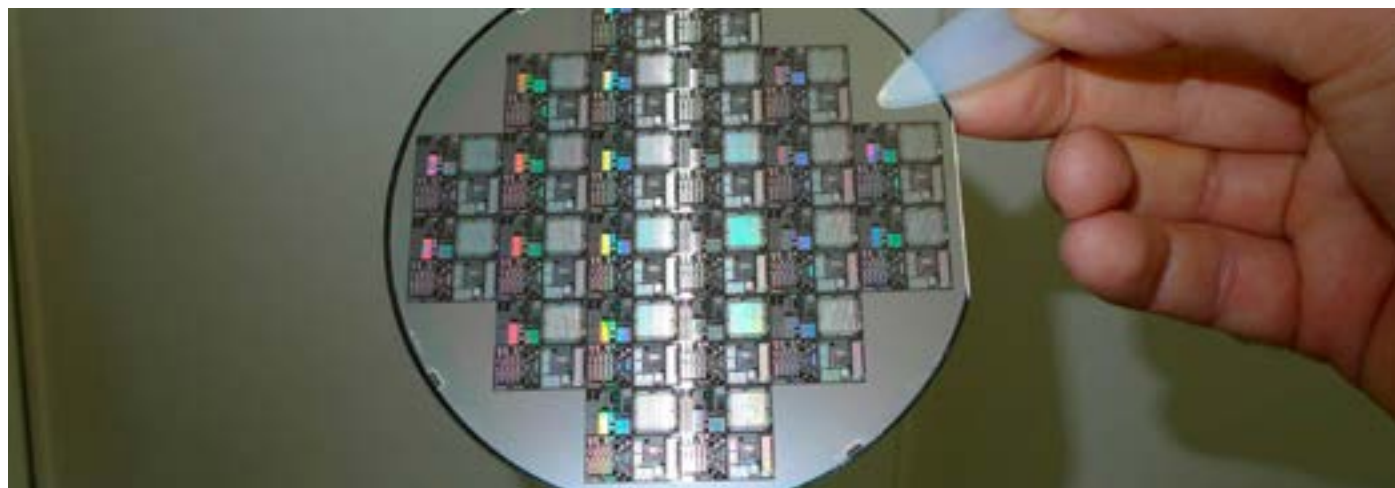
drive read/write heads. The result is a better quality "Exchange Bias" with characteristics that enable new functions for the magnetic devices of the future and mechanisms for exploring and better understanding the microscopic origin of this effect (47).

In the field of smart microsystems, the INF-NTC has obtained results that show it is possible to synchronise two optomechanical oscillators mechanically coupled on a nanometric scale. Synchronisation is basic for sharing data and functions between different microde-

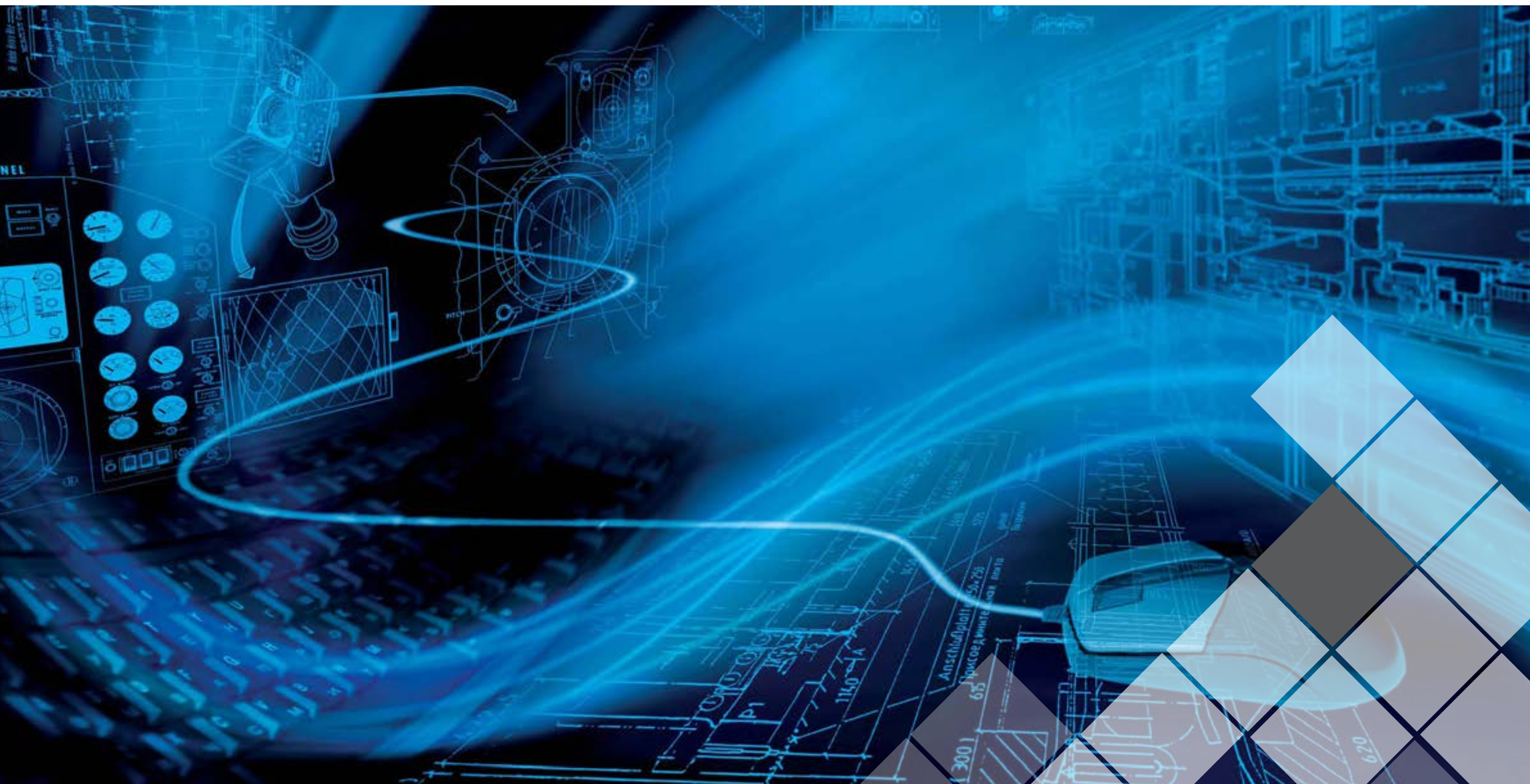
vices. To date, there have been very few studies demonstrating the synchronisation of this type of oscillator, past studies have even been contradictory. That is why this result represents huge progress for the on-chip synchronisation of microsystems, because it lays the foun-

dations for implementing reconfigurable networks of optomechanical oscillators with collective dynamics dominated by a weak mechanic coupling. Interest in integrating miniaturised devices in smart microsystems remains current. There are applications not only in communi-

cations, but also in manufacturing biosensors, which increase the functions relating to other microsystems (48).







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