INSTITUTE OF SPACE SCIENCES

Annual Report 2024

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An institute of the Spanish National Research Council (CSIC) affiliated with the Institut d'Estudis Espacials de Catalunya (IEEC). A 'María de Maeztu' Unit of Excellence

CSIC
Consejo Superior de Investigaciones Científicas

Institute of Space Sciences

25th Anniversary

Excelencia María de Maeztu

IEEC

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The ICE-CSIC 2024 Annual Report is the result of a collective effort of the ICE-CSIC personnel. We would like to thank everyone that contributed to the report.

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Foreword

As I reflect on 2024, my first year as ICE-CSIC Director, I am proud to share in this report the many achievements that have shaped this exciting and transformative period for our Institute.

Taking on this role has been a privilege, and I am grateful to be working alongside deputy directors Mar Mezcua and Serni Ribó. Together, our focus is on consolidating ICE-CSIC's remarkable growth, strengthening its position as a leading research centre in space sciences and Earth Observation, and fostering an environment that continues to attract top-tier scientists and engineers. A major step in this direction was the restructuring of our scientific departments into four distinct areas, reflecting better the scientific fields pursued by our researchers and facilitating stronger interdisciplinary collaboration.

Aldo Serenelli, ICE-CSIC Director.
Credits: Xavier Lapuente/ICE-CSIC.

In 2024, ICE-CSIC continued thriving. Our personnel kept growing, now comprising 161 members as of 31 December 2024 and including six newly appointed permanent staff. Our research excellence remains at the forefront, with 372 refereed publications spanning astrophysics, cosmology, and Earth observation.

2024 was also crucial for further cementing our role in groundbreaking space missions where ICE-CSIC has leading contributions. To highlight a few notable examples, LISA, the first gravitational wave observatory in space, entered its implementation phase with ESA's official adoption of the mission while Euclid released its first scientific results, showcasing its potential to unravel the mysteries of the dark Universe.

Financially, the Institute secured 19 new projects, including two ERC Advanced Grants and seven national plans, totalling 4.45 million euros in funding. As we enter the last year of the Maria de Maeztu funding, this is very important to consolidate the advancements achieved in the past years. As we grow, we have also invested in our infrastructure, with our Advanced Engineering Unit upgrading laboratories to enhance research capabilities.

Our commitment to training the next generation of scientists remained strong, welcoming six new PhD students, for a total of 45 students as of 31 December 2024, and celebrating five successful PhD defenses. The ICE-CSIC Summer School was focused on exoplanet studies this year and attracted over 40 international students who had the opportunity to learn and network with worldwide renowned experts in the field.

This year was particularly special as we celebrated our 25th anniversary on 21 December 2024—a moment to honor our past and set our sights on an ambitious future. In early 2025, we commemorated this milestone with a special conference to reflect on our journey and chart the path ahead.

As we step into 2025, I am excited about the opportunities ahead. ICE-CSIC's journey over the past 25 years has been extraordinary, and with the dedication of our talented team, I have no doubt that our future will be even brighter.

Aldo Serenelli, ICE-CSIC Director

1. ICE-CSIC at a glance

1.1. Overview and Mission

The Institute of Space Sciences (ICE-CSIC) is a research centre from the Spanish National Research Council (CSIC) that develops cutting-edge research in space sciences.

ICE-CSIC's research is focused on developing theoretical models and technologies to understand the Universe we live in, how it formed and evolved, and how it behaves. In this quest to solve the most challenging mysteries of the Universe, ICE-CSIC also uses space technologies to understand more about our planet Earth, to better model its climate change, and to develop predictive tools that could help avoid the effects of natural disasters.

ICE-CSIC achieved the María de Maeztu seal of excellence for the period 2022-2026, a recognition of its standing among the most important research centres in the country. ICE-CSIC also articulates CSIC's participation in the Institut d'Estudis Espacials de Catalunya (IEEC).

Located at the campus of the Universitat Autònoma de Barcelona in Bellaterra (Barcelona), ICE-CSIC comprises a diverse and international team of over 150 researchers, engineers and support staff.

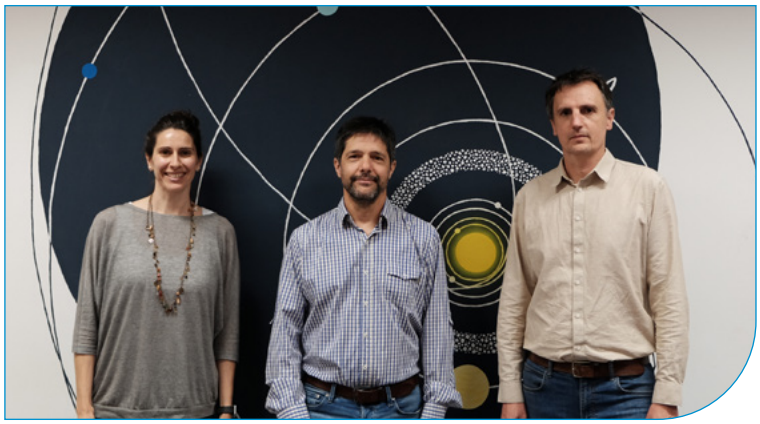
ICE-CSIC building.
Credits: César Hernández/CSIC Comunicación.

1.2. ICE-CSIC in 2024

The year 2024 was a remarkable one for ICE-CSIC due to the many accomplishments achieved by our members. In addition, 2024 was very special because ICE-CSIC reached its 25th anniversary. On 21 December 1999, CSIC officially created our institute and since then we have been at the forefront of scientific discovery and innovation. To commemorate this milestone, among other special actions, a special 25th anniversary conference was organised in early 2025 to reflect on our journey and envision our future.

Group picture of ICE-CSIC personnel at the 2024 Christmas party.
Credits: ICE-CSIC.

This year also comprised several important changes for the Institute. Most importantly, Aldo Serenelli officially became the new ICE-CSIC director. Together with him, the new ICE-CSIC Managing Team is composed of Mar Mezcua and Serni Ribó, who have been appointed scientific and technical deputy directors, respectively. A main goal for the Managing Team 4-year term will be to consolidate the growth that ICE-CSIC has experienced in the last few years and to strengthen its position as a leading research centre in Spain and Europe by building up on the scientific and technological excellence present at the institute.



ICE-CSIC Managing Team (from left to right): Mar Mezcua (Scientific Deputy Director), Aldo Serenelli (Director) and Serni Ribó (Technical Deputy Director).
Credits: ICE-CSIC.

Another important change was the restructuring of the former two science departments into four new departments, namely: Planetary Systems and Earth Observation; Star formation, Stellar and High-energy Astrophysics; Nuclear, Gravitational Wave and Multi-messenger Astrophysics; and Extragalactic Astrophysics and Cosmology.

Explore

Visit of the International Advisory Committee

Group picture of the IAC Review Meeting. From left to right: Serni Ribó, Mar Mezcua, Aldo Serenelli, Marcella Marconi, Michael F. Bode, Giuseppina Micela, Gillian Wright and Luigi Stella.
Credits: ICE-CSIC.

On 2-4 December 2024, ICE-CSIC received the visit of its International Advisory Committee (IAC) for its periodic review. During the visit, the IAC members attended a full programme of talks by ICE-CSIC members regarding the activities of the institute and visited the institute facilities. This was the first in-person IAC visit since 2019 (before the COVID-19 Pandemic) and the committee was highly impressed of the achievements accomplished by the Institute since their last in-person visit. As they expressed in their early review ¨We were again extremely impressed with what we have seen, both in terms of the scientific breadth and depth of the research and technology development undertaken at the Institute, but also in terms of the quality of the management and enthusiasm of the staff."

The IAC members visiting our institute were Marcella Marconi (INAF - Osservatorio Astromico di Capodimonte), Michael F. Bode (Astrophysics Research Institute), Giuseppina Micela (Osservatorio di Palermo), Gillian Wright (UK Astronomy Technology Centre & Site Royal Observatory Edinburgh) and Luigi Stella (INAF - Osservatorio Astronomico di Roma), while Manuel Martín-Neira (ESA, European Space Research Center, Noordwijk) and Francis Bernardeau (Institute of Astrophysics of Paris) joined remotely to take part in the evaluation and preparation of the IAC report.

The Institute kept growing during 2024 up to a total of 161 ICE-CSIC personnel as of 31 December 2024. From those, we were happy to welcome six permanent positions: Weiqiang Li, Anaëlle Maury and Alessandro Patruno as new Faculty members; Xavier Mestre as Deputy Manager, Isabel Pérez as Project justification Manager and José Luis Gálvez as Qualified Professional in Engineering. Throughout the year, our former Accounting and Finance manager Guadalupe Masip retired after 14 years working at the Institute.

The research performed at our Institute continued excelling in many areas of astronomy and Earth observation with a total of 372 refereed publications by ICE-CSIC researchers. The highlights include the discovery of a magnetar flare coming from the bright galaxy M82 (Mereghetti et al. 2024); the first detection of a significant and rapid dust formation process in supernova Ia interacting with circumstellar gas (Wang et al. 2024); the detection of three neutron stars too cold for their age (Marino et al. 2024); the first time that supermassive black holes have been detected at the so-called 'Cosmic Noon', about 10 billion years ago, in low-mass galaxies (Mezcua et al. 2024); the discovery of the nearest, transiting, temperate, Earth-size world located to date (Kuzuhara et al. 2024); and the PAUS survey releasing a new cosmic distance catalogue with 1.8 million astronomical objects (Navarro et al. 2024 and Castander et al. 2024).

2024 was also very important for the space missions in which ICE-CSIC participates. LISA, the first gravitational wave observatory in space, was officially adopted by the European Space Agency (ESA) Science Programme Committee giving the go-ahead to build the instruments and spacecraft and therefore entering the implementation phase, with a launch expected in 2035. The scientific contribution in Spain is led by

ICE-CSIC and IEEC. The ICE-CSIC team members are also involved in the development of ILIADA (In-Orbit LISA Diagnostics Demonstrator), a LISA technology demonstrator selected to fly in the GENEO-02 CubeSat, the forthcoming satellite promoted within the NewSpace strategy from Generalitat de Catalunya with expected launch in 2026.

Euclid, the M2 ESA mission in which ICE-CSIC has a leading role, released its early scientific papers, demonstrating Euclid's ability to unravel the secrets of the cosmos and enable scientists to hunt for rogue planets, use lensed galaxies to study dark matter, and explore the evolution of the Universe. During 2024, we also witnessed the launch of Einstein Probe in January and of Hera in October. Einstein Probe will explore the sky for 3 years looking for new X-ray transients to better understand the most extreme objects in the Universe. Hera will study the binary asteroid system formed by Didymos and Dimorphos, carrying out several experiments to better understand potentially hazardous asteroids.

The ICE-CSIC Advanced Engineering Unit (AEU) has developed several improvements of ICE-CSIC's laboratories to offer better services to the engineers and experimental researchers working at the Institute. In this respect, the Technical Room has been expanded to include new machinery to service the Optical Lab. Another important improvement has been the sanitation of the air supply for the Microscopy Clean Room. Additionally, a nitrogen line and oxygen detectors have been installed in all laboratories. Regarding the purchase of equipment, the AEU acquired a new high-frequency and high-performance oscilloscope that serves the entire range of frequencies used in the different missions where the Institute participates.

ICE-CSIC continued providing opportunities in 2024 for international students and early career researchers to develop their professional careers, including the participation in Master's and PhD programme opportunities. For the latter, we welcomed 6 PhD students during the year, reaching a total of 45 PhD students as of 31 December. In 2024, 5 PhD students (Benjamín Camacho, Abubakr Ibrahim, David Navarro, Eloy Peña-Asensio and Michele Ronchi) successfully defended their PhD theses. Another important event was the organisation of the 7th ICE-CSIC Summer School, which welcomed 42 early-career researchers from 17 different countries who spent two weeks at the Institute learning about exoplanets from renowned experts in the field.

Explore

Two ERC Advanced Grants to explore the nature of stars and planets

SPOTLESS (ERC Advanced grant - 2.5 M€ - PI Ignasi Ribas)
The SPOTLESS project seeks to improve the search for exoplanets, particularly those that are similar to Earth, called exo-Earths. The goal of the SPOTLESS project is to develop a comprehensive strategy to model and mitigate the impact of stellar activity and thus be able to find and characterise exo-Earths in a totally reliable way.

PEBBLES (ERC Advanced grant - 1.98 M€ - PI Anaëlle Maury)
The PEBBLES project takes an unprecedented look at interstellar dust to understand how stars and their planets form. The goal of the project is to discern the size of tiny grains of dust located light-years away from Earth, in areas where new stars are emerging.

This was also a great year regarding grants and contracts managed by the Institute, with the acquisition of 19 new projects and a total funding of 4.45 million euros. This included two ERC Advanced Grants (see in previous page), participation in the Horizon Europe Marie Skłodowska-Curie GLITTER PhD network to train the next generation of Earth observers, and 7 new National Plans.

ICE-CSIC hosted 8 international workshops and meetings during the year, including the organisation of scientific workshops for the Euclid and LISA missions as well as the school for the GLITTER PhD network. These meetings were useful to advance the work of key aspects of these space missions and European networks.

The Institute also organised two colloquia welcoming the Chair of the Cradle of Life SKA's Working Group Cherry Ng and the IAA-CSIC science deputy director Isabel Márquez. Another special talk we hosted was the Christmas Special Seminar by Laura Lechuga from the Catalan Institute of Nanoscience and Nanotechnology (ICN2).

Explore

ICE-CSIC participates in the recognition ceremony for the Severo Ochoa and María de Maeztu accreditations

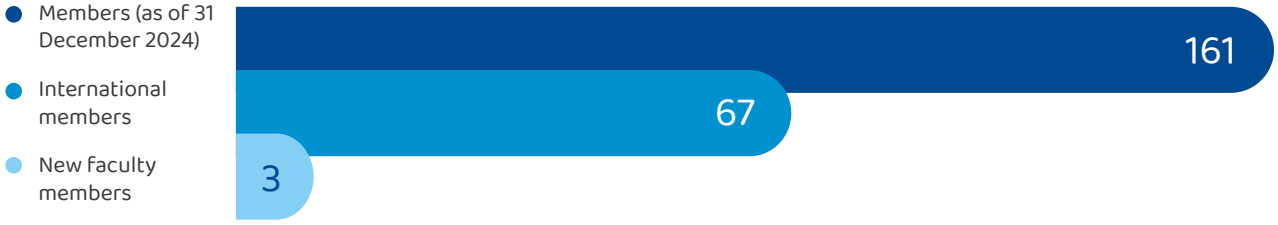
Group picture of institute's directors accepting the Severo Ochoa and María de Maeztu accreditations, including Diego Torres (third to the right) on behalf of ICE-CSIC, with the Science Minister Diana Morant.
Credits: Ministry of Science, Innovation and Universities (MICIU).

ICE-CSIC participated in the recognition ceremony for the Severo Ochoa and María de Maeztu accreditations, awarded by the Spanish Ministry of Science, Innovation and Universities (MICIU), through the Spanish State Research Agency. The event was held on September 6th, in Madrid and was chaired by the Minister of Science, Innovation and Universities, Diana Morant.

2024 continued the ICE-CSIC tradition of organising Pizza Seminars every Friday with 32 pizza seminars with speakers both from inside and outside the Institute covering all fields of astronomy and space sciences. The Institute also hosted the 2nd Cross-Collserola PhD Meeting in Astrophysics, Cosmology and Particles 2024, which acted as a meeting point for PhD students in research centres in the Barcelona region.

ICE-CSIC continued its enduring commitment to foster public engagement initiatives. Among the actions of the ICE-CSIC Communication and Outreach Office, we could highlight our participation in the Magnet Alliance with the Gabriel Castellà i Raich school in Igualada (Barcelona) to fight school segregation for third year in a row; our visit to the Sahrawi refugee camps near Tindouf (Algeria) to perform astronomy hands-on activities at schools in the framework of the Amanar project; a pilot activity for visually impaired people using astronomy 3D tactile materials as well as participation in major science outreach festivities in the region such as Festa de la Ciència 2024 in Barcelona, and the European Researchers' Night.

Key figures in 2024



372 peer-reviewed publications

93% of publications in 1st quartile journals

1 publication in Nature

4 publications in Nature Astronomy

4 publications in Nature Communications

2,825 TOTAL CITATIONS

60 Active projects

19 New projects

4.45 Million EUR funding new projects

32 Pizza seminars

>100 Seminars & outreach talks

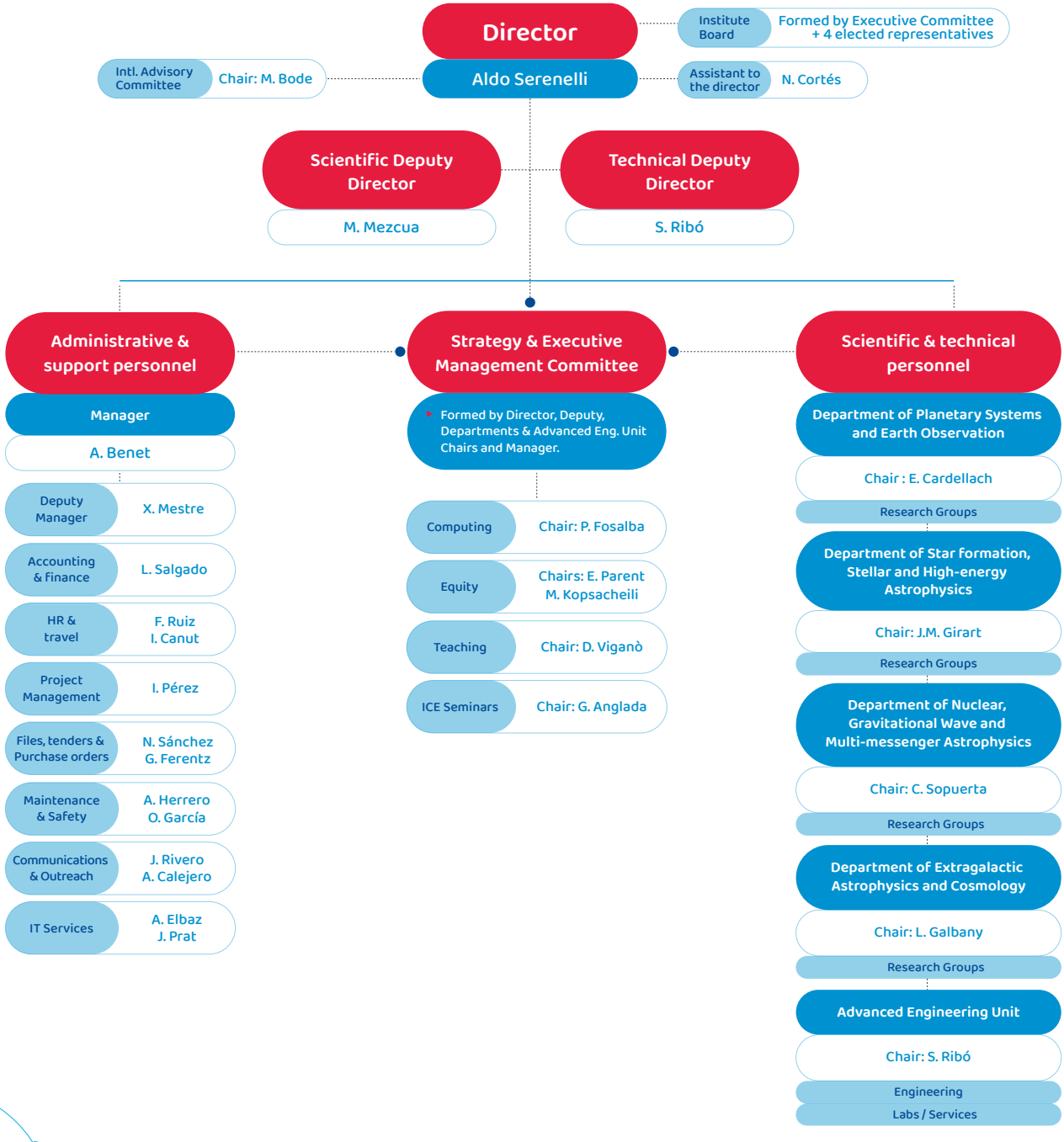
3 AWARDS

21	Press releases
1,262	Media impacts in Spanish media
173,164	People reached by ICE-CSIC communication actions
4,393 million	People extended reach with media coverage

2. Management

The ICE-CSIC is organised in four departments: the Planetary systems and Earth Observation Department; the Star formation, Stellar and High-energy Astrophysics Department; the Nuclear, Gravitational Wave and Multi-messenger Astrophysics Department; and the Extragalactic Astrophysics and Cosmology Department. In addition, there is a technical unit, the Advanced Engineering Unit (AEU), which ensures the development of the institute's technological research lines and assets and supports the technological needs of the four aforementioned departments. At a formal scientific level, there are about 22 research groups at the institute, typically composed of more than 10 members, with 2-4 faculty in each of them. Research groups are fluid at ICE-CSIC, and it is common to see cross-interaction among members from different formal groups, even from different departments, as the institute focuses on around twenty research lines.

Besides these scientific units, the formal bodies that structure the centre are the Director's Office, the Institute Board, the Strategy Committee, and the International Advisory Committee. Finally, we have several other committees aimed to coordinate different matters of the institute.

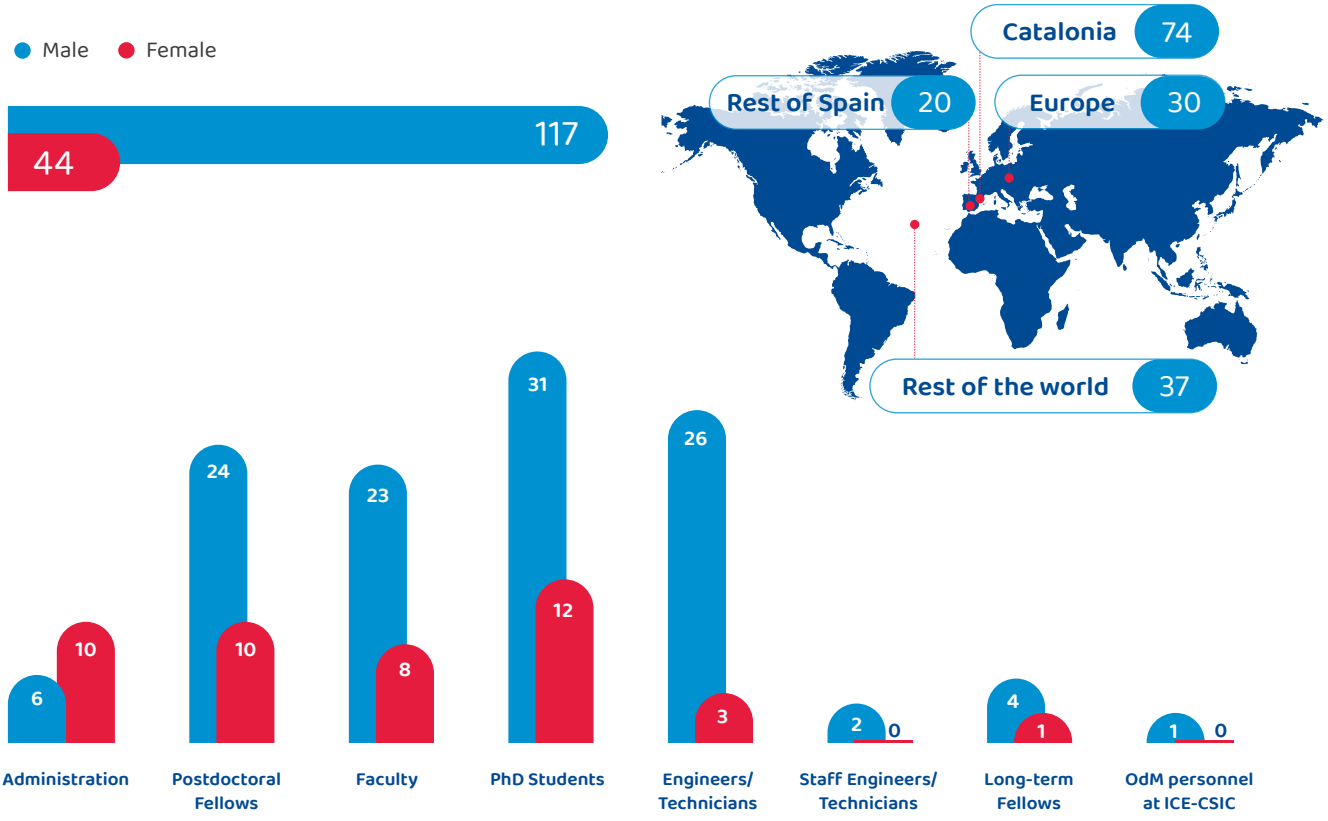


3. People

We are a diverse and international team of researchers, engineers and support staff. As of 31 December 2024, there are 161 people working at ICE-CSIC. This is an increase of 3,9% in comparison with the end of 2023.

AGN Group meeting. From left to right: Victor Rodríguez, Mònica Villaret, José Alcolea, Mar Mezcua and David Domínguez.
Credits: ICE-CSIC.

3.1. Personnel



Administration

Benet, Àngels
Calejero, Alba
Canut, Iolanda
Cortés, Noemí
Elbaz, Ángel
García, Óscar
Herrero, Ángel
Mestre, Xavier
Pérez, Isabel
Pino, Cristina
Prat, Joan
Ripoll, Maribel
Rivero, Jorge
Ruiz, Fina
Salgado, Laura
Sancho, Núria

Postdoctoral Fellows

Breton, Michel-Andrès
Casas, Ricard
Celora, Thomas
De Grandis, Davide
De Sarkar, Agnibha
Gomes, Nuno
Gouyou, Sylvain
Gutiérrez, Claudia
Han, Ilseung
Herrera, Yago
Khurshudyan, Martiros
Kopsacheili, Maria
Kovlakas, Konstantinos
Liao, Li Wen
Lenzi, Michele
Marino, Alessio
Mestre, Enrique
Meyer, Dominique
Morales, Juan Carlos
Morata, Oscar
Müller, Tomás
Nèmec, Nina
Noll, Anthony
Navarrete, Felipe
Parent, Emilie
Parimbelli, Gabriele
Perger, Manuel
Psaridi, Angeliki
Radinovic, Slađana
Ramakrishnan, Sujatha
Ronchi, Michele
Säppi, Saga Aurora
Sato, Asako
Sengupta, Soumya

Faculty

Anglada, Guillem
Cardellach, Estel
Castander, Francisco
Crocce, Martin
Elizalde, Emilio (Emeritus)
Fosalba, Pablo
Galbany, Lluís
Gaztañaga, Enrique
Girart, Josep Miquel
Hernanz, Margarita
Husa, Sascha
Isern, Jordi (Emeritus)
Kemper, Francisca
Li, Weiqiang
Manuel, Cristina
Maury, Anaëlle
Mezcua, Mar
Nofrarias, Miquel
Odintsov, Sergei D.
Patruno, Alessandro
Rea, Nanda
Ribas, Ignasi
Ribó, Serni
Rius, Antonio (Emeritus)
Serenelli, Aldo
Sopuerta, Carlos
Tolos, Laura
Torrelles, José María (Emeritus)
Torres, Diego F.
Trigo, Josep M.
Viganò, Daniele

Staff Engineers/Technicians

Colomé, Josep
Martín, Víctor

Long-term Fellows

Alarcon, Alex
Coti Zelati, Francesco
Montes, Mireia
Padullés, Ramon
Sánchez, Álvaro

Engineers/Technicians

Aguilar, Eduard
Álvarez, Daniel[1]
Ballber, Pau
Campos, Néstor
Canal, Miquel
Canalda, Xavier[1]
Carmona, Alex
Cirera, Josep Maria
Costa, Jan Marc
Ferentz, George
Gálvez, José-Luis
García, Alberto
Herencia, Daniel
Karimbu, Arshad
Komorowski, Przemyslaw
Martí, Laura
Montoro, Álvaro
Nakhjiri, Nariman
Oliveras, Santiago
Pérez, Ana
Roma, David
Salvans, Josep
Serrano, Santiago
Serrano, Daniel
Sisteré, Sofia
Soldevila, David
Vallés, Ramon
Verderi, Axel
Tomás, Álex

PhD Students

Alburai, Alaa
Alemany, Marc
Anguera, Alèxia
Baghkhani, Zahra
Blanco, Jordi
Blázquez, Carles
Camacho, Gisela
Çoban, Ömer Faruk
Coloma, Jose María
D'Onofrio, Simone
Díaz, Elena
Díaz, Pedro
Du, Hao
Elias, Albert
Eróstegui, Alejandro
Fernández, Pablo
Gambardella, Giosuè
González, Guillermo
Gonzalez, Maider
Grèbol, Pau
Gualani, Vivek
Hernández, José Luis
Huang, Bo
Íñiguez, Daniel
Jiménez, Cristina
Kaur, Simranpreet
Martín, Iván
Pardo, Celsa
Paz, Antía
Peng, Jilun
Phan, Kim
Porqueras, Óscar
Pirvu, Rebeca
Rodríguez, Carlos
Rodríguez, Víctor
Soriano, Clàudia
Torki, Maryam
Untzaga, Julen
Wan, Yiqing
Viglione, Cristian Nery
Zhang, Wei
Zhou, Xin
Zuleta, Andrés

Montsec Observatory (OdM) personnel at ICE-CSIC

Herrero, Enrique

[1] X. Canalda and D. Álvarez are also doing their PhD theses at ICE-CSIC, see Section 8.2.

3.2. New Faculty Members

Weiqiang Li

Weiqiang Li received the Bachelor of Engineering and PhD degrees in 2004 and 2012, respectively, from Beihang University (BUAA), Beijing, China. His PhD focused on the signal processing techniques and new instrumentation on Earth observation using reflected signals from Global Navigation Satellite System (GNSS).

In 2012 he started his first postdoc at the School of Electronic and Information Engineering (EIE) in BUAA. That same year, he was awarded ESA's international postdoc fellowship to work at the ESA European Space Research and Technology Center, the Netherlands, where he was advised by Manuel Martín-Neira, the inventor of the GNSS-Reflectometry (GNSS-R) concept, to work on the definitions and analyses of new spaceborne GNSS-R missions. In 2013 he took the leading role of the GNSS-R research line at EIE. He was a visiting scientist at ICE-CSIC between 2014 and 2016 in the frame of ESA-China GNSS-R cooperation. Since 2016, he has continued working at ICE-CSIC as a contracted researcher. In 2021 he obtained a Ramon y Cajal fellowship and in 2024 he became Científico Titular at ICE-CSIC.

Throughout his career, Weiqiang Li has been motivated by contributing to a sustainable and efficient Earth observation system. His studies focus on different aspects of GNSS remote sensing techniques, which includes discovering scientific applications and development of enabling technologies with the due and necessary consideration of the users: space agencies and geoscientists. His scientific contributions comprise advancing theories and applications of GNSS-R in geosciences, developing novel processing and instrumental algorithms, and creating theoretical models. These contributions

Wieqiang Li.
Credits: Wieqiang Li.

have resulted in significant discoveries that have either reinforced the feasibility and performance of existing concepts, such as cyclone wind speed retrieval and group delay altimetry, or enabled new GNSS-R Earth Observation capabilities, such as carrier phase altimetry, sea ice thickness, ice sheet melt detection, and monitoring of wetlands and inland water. In addition, he has been also working on the developments of new processing and simulation techniques and corresponding hardware/software tools, which have been transferred to space agencies and industries.

Weiqiang Li has been actively involved in different spaceborne Earth Observation missions. He was the research team member of ESA's GEROS-ISS experiment, and the proposal team member of the G-TERN mission, in response to ESA EE9 mission call. He is also the science team member of the 2nd ESA Scout mission HydroGNSS. In addition, he has been also involved in NASA's CYGNSS mission as the extended science team member, and Chinese Bufeng-1 A/B mission through an ESA-China international cooperation programme.

Anaëlle Maury

Anaëlle Maury is an astrophysicist who investigates the birth of stars like our Sun, and the physics to build the first seeds for planets around them. She earned her PhD in 2009 from the University Paris Saclay in Paris, France.

Her research focuses on understanding the processes responsible for the properties of stars when they form in our galaxy, with a special focus on the role of magnetic fields to shape the first seeds of protoplanetary disks. She has been a pioneer in studying together the properties of the youngest protostellar disks and the magnetic properties of their

Anaëlle Maury.
Credits: Anaëlle Maury.

environments, using the most advanced techniques for analysis of interferometric data as well as for comparing them to realistic synthetic observations of Magnetohydrodynamic (MHD) models. Her work has allowed her to uncover the regulation of disk formation by magnetic fields in the youngest protostars of the Galaxy, and to contribute greatly to solving the long-standing angular momentum problem for the formation of stars.

She is now an ICREA research professor at ICE-CSIC, where she will develop her group with the ERC Advanced Grant PEBBLES. At ICE-CSIC, her team is dedicated to studying the physics at work for the early evolution of astrophysical dust into small solid particles that will become planetary systems. Using state-of-the-art astronomical data from the most advanced observatories (ALMA, JWST, NOEMA) her team is confronting predictions from new numerical MHD models that contain all the relevant physical processes, and for the first time including grain evolution physics.

Alessandro Patruno

Alessandro Patruno completed his PhD at the University of Amsterdam (the Netherlands) in 2009 and has since held positions as a Veni Fellow there, a Vidi Fellow at Leiden University (the Netherlands), and a Ramón y Cajal researcher at ICE-CSIC. His research covers the physics of compact objects and their environments, focusing on neutron stars and the dynamic processes they exhibit.

Early in his career, Patruno became intrigued by the interplay between accretion and magnetic fields in binary systems, which led him to explore disk–magnetospheric interactions and the instabilities that trigger X-ray pulsations. These investigations naturally extended into developing theoretical models of stellar evolution in accreting binaries, as well as probing the potential for planets around neutron stars and even assessing their habitability in such extreme environments.

In parallel, he has developed deep pulse searches with novel techniques that have attempted the discovery of sub-millisecond pulsars to potentially place new constraints on the equation of state of ultra-dense matter. His work on accreting systems also includes studies of gravitational-wave emission and thermonuclear bursts, each providing complementary insights into the complex physics at play in such extreme objects. These efforts are complemented by recent interest in applying advanced deep learning techniques to sift through large datasets and reveal subtle patterns in the behavior of astrophysical systems. He has also been actively involved in experimental astrophysics, for example, ideating and then contributing to the development of a quantum optics detector aimed at measuring the orbital angular momentum of light from astrophysical sources. His role in mission planning, notably as deputy Principal Investigator for the Wide Field Monitor on the eXTP mission, has further enriched his perspective.

Alessandro Patruno.
Credits: Alessandro Patruno.

Throughout his career, he has focussed on observational data while trying to keep a clear theoretical understanding of the systems under investigation, and novel methodologies in a manner that reflects the multifaceted nature of high-energy astrophysics. Whether studying the subtle signatures of X-ray pulsations, the explosive behavior of thermonuclear bursts, or innovative detection techniques, Patruno's work is driven by a desire to uncover new layers of understanding in the Universe. This integrated approach has allowed him to explore a diverse array of topics within compact object physics, always seeking to connect the detailed physics of individual systems to the broader astrophysical questions of stellar astrophysics and the fundamental physics questions of the extreme states of matter.

3.3. Guest researchers

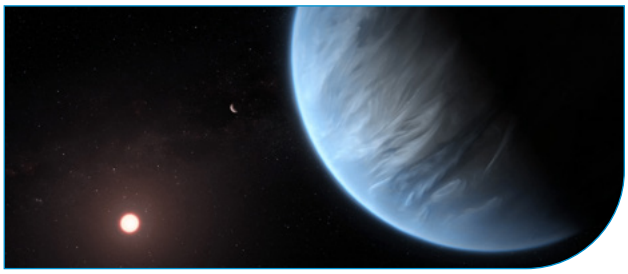
During the year, we have received 36 visiting scientists at ICE-CSIC. Most of them (21) stayed for longer than two weeks.

1. **Marretta, A.**, Università degli Studi di Palermo, 10/2/2023 - 3/1/2024
2. **Saha, P.,** National Astronomical Observatory of Japan, 19/2/2024 - 19/3/2024
3. **Pereyra, L.A.**, Instituto de Astronomía Teórica y Experimental (IATE), 23/2/2024 - 30/7/2024
4. **Illiano, G.**, National Institute for Astrophysics (INAF), 25/2/2024 - 26/3/2024
5. **Tutusaus, I.**, Institut de Recherche en Astrophysique et Planétologie-Observatoire Midi-Pyrénées, 1/3/2024 - 31/12/2024
6. **Eggemeier, A.**, Argelander-Institute for Astronomy University of Bonn, 10/3/2024 - 16/3/2024
7. **Fernández López, M.**, Instituto Argentino de Radioastronomía, 8/4/2024 - 11/7/2024
8. **Folatelli, G.**, Instituto de Astrofísica de La Plata, 18/4/2024 - 4/5/2024
9. **Méndez Llorca, A.N.**, Instituto de Astrofísica de La Plata, 18/4/2024 - 19/5/2024
10. **García Lambas, D.R.**, Instituto de Astronomía Teórica y Experimental (IATE), 6/5/2024 - 7/7/2024
11. **Curiel Ramírez, S.**, Instituto de Astronomía, Universidad Nacional Autónoma de México (IA-UNAM), 16/5/2024 - 31/5/2024
12. **Riquelme, W. E.**, Universidade Estadual Paulista (UNESP), 25/5/2024 - 7/7/2024
13. **Siudek, M.**, Instituto de Astrofísica de Canarias, 1/6/2024 - 13/7/2024
14. **Sato, A.**, Kyushu University (Japan), 3/6/2024 - 17/6/2024
15. **Rodríguez Kamenetzky, A.**, Instituto de Astronomía Teórica y Experimental (IATE), 8/6/2024 - 31/10/2024
16. **Ülgen, A.**, Bilkent University, 9/6/2024 - 1/9/2024
17. **Dharmawardena, T.**, New York University, 17/6/2024 - 21/6/2024
18. **Zuleta Serrano, A.**, Ludwig-Maximilians-Universität München, 25/6/2024 - 18/7/2024
19. **Meunier, N.**, Institut de Planétologie et d'Astrophysique de Grenoble (IPAG), 4/7/2024 - 5/7/2024
20. **Nortman, L.**, Institut für Astrophysik und Geophysik-Georg-August-Universität Göttingen, 5/7/2024 - 5/7/2024
21. **Gnessmeier, J. M.**, Laboratory of Physics and Chemistry of the Environment, 7/7/2024 - 11/7/2024
22. **Ilin, E.**, ASTRON, 7/7/2024 - 13/7/2024
23. **Boro Saikia, S.**, University of Vienna, 9/7/2024 - 11/7/2024
24. **Kim, W.**, I. Physikalisches Institut-University of Cologne, 25/7/2024 - 2/8/2024
25. **Fuller, G.**, I. Physikalisches Institut-University of Cologne, 25/7/2024 - 2/8/2024
26. **Ferrer, E. J.**, The University of Texas Rio Grande Valley, 1/9/2024 - 31/12/2024
27. **Raveloarison, H.H.**, Freie Universität Berlin, 5/9/2024 - 17/10/2024
28. **Chi Yan Law,**. INAF-Osservatorio Astrofísico di Arcetri, 17/9/2024 - 11/10/2024
29. **Caporaso, F. M.**, Instituto de Astronomía Teórica y Experimental (IATE), 10/9/2024 - 22/3/2025
30. **Feng, B.**, School of Physics-Huazhong University of Science and Technology, 15/10/2024 - 30/11/2024
31. **Orellana, M.**, Lab. de Investigación Científica en Astronomía, Universidad Nacional de Río Negro, 20/10/2024 - 3/11/2024
32. **Chen, S.**, Politecnico di Milano, 1/11/2024 - 30/4/2025
33. **Elias-Rosa, N.**, INAF-Astronomical Observatory of Padova, 15/11/2024 - 15/11/2025
34. **Mahani, H.**, Institute for Research in Fundamental Sciences, 25/11/2024 - 5/12/2024
35. **Sciotti, D.**, Sapienza University of Rome, 2/12/2024 - 13/12/2024
36. **Saha, P.**, National Astronomical Observatory of Japan, 4/12/2024 - 20/12/2024

4. Departments

Planetary Systems and Earth Observation

The Planetary Systems and Earth Observation Department works on theoretical, observational and experimental projects and missions the objectives of which span from boosting the knowledge of our planet using spaceborne techniques to the discovery and characterisation of planetary systems around other stars, or the study of the secrets contained in asteroids, comets and meteorites, with clues on the accretionary processes occurred in our planetary system.

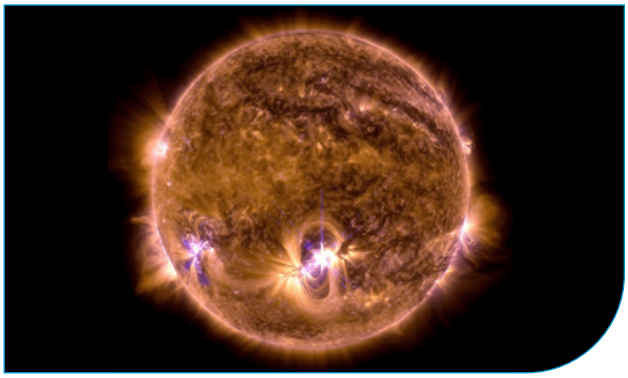


Main research lines

- New spaceborne Earth Observation techniques using opportunistic sources
- Magnetism in exoplanetary systems
- The star-planet connection
- Asteroids, comets, and meteorites

Star formation, Stellar and High-energy Astrophysics

The research in the Star formation, Stellar and High-energy Astrophysics Department is focused on the physical processes associated with stars, from their formation in the densest regions of the interstellar medium, through their evolution and death, including the stellar final remnants (white dwarfs and neutron stars). The research covers the full electromagnetic spectrum, with special focus on the highest (Gamma and X-rays) and lowest (Infrared and Radio) energy regimes. The department is also involved in the development of instrumentation and software solutions for ground- and space-based high energy astrophysical facilities.

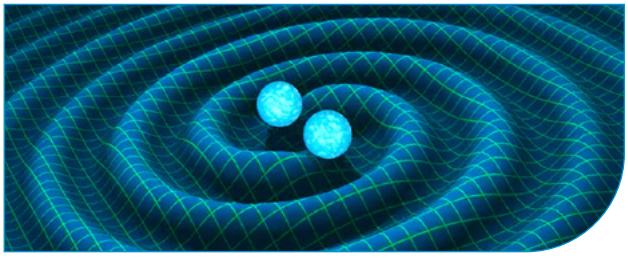


Main research lines

- Multimessenger astrophysics
- Star and planet formation
- The Sun, stellar evolution, and asteroseismology
- Nova explosions, models nucleosynthesis, and high-energy emission of X and Gamma-rays
- Physics of white dwarf and related phenomena
- Plasma-magnetic fields interactions in pulsars and their environments
- X-Ray binaries and Accretion

Nuclear, Gravitational Wave and Multi-messenger Astrophysics

The primary scientific goal of the Nuclear, Gravitational Wave and Multi-messenger Astrophysics Department is to do research in nuclear physics, gravitational wave physics and in multi-messenger astrophysics with the goal of understanding compact objects like neutron stars, black holes, and the nature of the gravitational interaction. To that end, we carry out observational and theoretical studies that include multi-messenger observations and the development of instrumentation. Regarding observations we mainly use, but are not limited to, X-ray and gravitational waves.



Main research lines

- Extreme compact objects in the transient multi-band sky
- Gravitational Wave Theory
- Nuclear and Particle Astrophysics
- Experimental gravitational astronomy

Extragalactic Astrophysics and Cosmology

The Extragalactic Astrophysics and Cosmology Department investigates the fundamental laws and origins of the Universe, using observational data and models to answer foundational cosmological questions. Our research spans early-Universe evolution, modified gravity, galaxy formation, and large-scale cosmic structure. We study supernovae as both probes for stellar death and as tools for measuring cosmic distances and expansion, and massive black holes, exploring their roles in shaping galaxies and their environments. By combining theoretical and observational approaches, we aim to clarify the complex mechanisms governing the Universe's structure, blending simulations with experimental data for a comprehensive understanding of cosmic evolution.

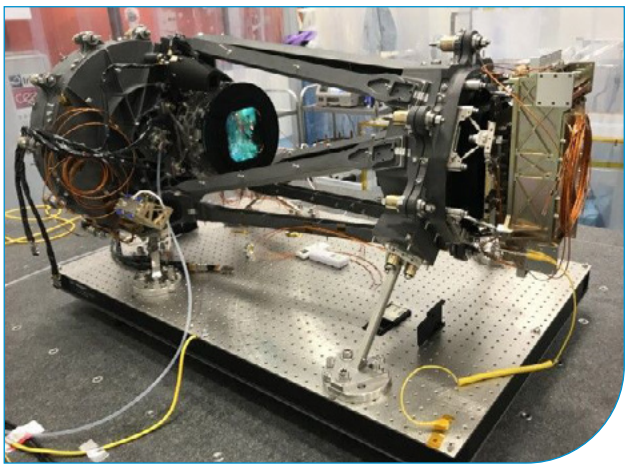
Main research lines

- Analysis tools for large-scale galaxy surveys
- Modified gravities
- Active Galactic Nuclei and Galaxy Evolution
- The Low Surface Brightness Universe
- Supernovae and stellar transients
- MICE Stimulations
- The Black Hole Universe

Advanced Engineering Unit

The Advanced Engineering Unit (AEU) does overall management and supports the development of the institute's technological research lines and assets. The AEU is responsible for providing ICE-CSIC's technological expertise that allows the institute to participate in the development of new missions and astronomical observatories.

This unit works together with project's Principal Investigators to support the development of the technological aspects of the project, including the strategic value of keeping the know-how for future projects. Among other tasks, AEU members support ICE-CSIC staff with the design, implementation and testing of electronic hardware, software and mechanical parts. The AEU also runs the laboratories of the institute.



AEU Laboratories

- Payload Laboratory
- Integration Laboratory
- Astronomy Laboratory
- Clean Room
- Microscopy Clean Room
- Optical Laboratory
- Radiation Laboratory
- 3D Printing Laboratory

5. Research highlights

5.1. Magnetar flare detected in a galaxy near the Milky Way

An international team, including ICE-CSIC participation, using ESA's Gamma-ray space telescope Integral, spotted a magnetar flare coming from the bright galaxy M82. For only a tenth of a second, a short burst of energetic gamma-rays appeared from the direction of the bright galaxy M82. The satellite data were received in the Integral Science Data Centre in Geneva (Switzerland), from where a gamma-ray burst alert was sent out to astronomers worldwide, only 13 seconds after its detection. The IBAS software gave an automatic localisation coinciding with the nearby galaxy M82.

The team requested ESA's XMM-Newton space telescope to perform a follow-up observation of the burst's location as soon as possible. If this had been a short gamma-ray burst, caused by two colliding neutron stars, the collision would have created gravitational waves and have an afterglow in X-rays and visible light.

The team used ground-based optical telescopes, including the Italian Telescopio Nazionale Galileo and the French Observatoire de Haute-Provence, to look for a signal in visible light, but they did not find anything.

The discovery of this magnetar in such a far-away starburst galaxy can help us understand the reach of the strong magnetic activity in the population of young neutron stars as a function of the different host galaxies and environments, something crucial also for other transient events such as Fast Radio Bursts and Gamma-Ray Bursts.

The discovery of a magnetar in M82, a bright galaxy where vigorous star-formation takes place, confirms that magnetars are likely powerful young neutron stars. The search for more magnetars will continue in other star-forming regions, to understand these extraordinary astronomical objects.

When stars more massive than eight times the Sun die, they explode in a supernova that leaves a black hole or neutron star behind. Neutron stars are very compact stellar remnants more massive than the Sun packed into a sphere the size of a city. They rotate quickly and have strong magnetic fields.

However, in the past 50 years of gamma-ray observations, only three giant flares have been seen from magnetars in the Milky Way or in a close-by galaxy. These outbursts are very strong: one that was detected in December 2004 came from 30,000 light-years from us but was still powerful enough to affect the upper layers of Earth's atmosphere. Similar to how solar flares, coming from much closer to us, influence it.

However, outbursts of such short duration can only be captured serendipitously when an observatory is already pointing in the right direction.

Published in Mereghetti, S., et al., incl. **Rea, N.** (2024), *A magnetar giant flare in the nearby starburst galaxy M82*, Nature, 629, 58, 10.1038/s41586-024-07285-4.

Text adapted from the press release published at the ICE-CSIC website.

Artistic impression of a magnetar.
Credits: BCSS/Mt. Visual.

5.2. A new source of dust in the universe discovered: type Ia supernova

An international study with ICE-CSIC participation discovered a previously unknown source of dust in the Universe: a Type Ia supernova interacting with gas from its surroundings. The results are significant because the exact nature of dust creation in the Universe has been a mystery for a long time. This research marks the first detection of a significant and rapid dust formation process in the thermonuclear supernova interacting with circumstellar gas.

Supernovae have been known to play a role in dust formation and, to date, dust formation has only been seen in core-collapse supernovae (or type II), which are the explosions of massive stars. Since core-collapse supernovae do not occur in elliptical galaxies, the nature of dust creation there has remained elusive. These galaxies aren't organised into a spiral pattern like our Milky Way galaxy, but are giant swarms of stars. The study finds that thermonuclear Type Ia supernovae may account for a significant amount of dust in these galaxies.

The researchers monitored the supernova SN 2018evt for over three years using space-based facilities like NASA's Spitzer Space Telescope and NEOWISE missions, and ground-based facilities like the Las Cumbres Observatory's global network of telescopes, and other facilities in China, South America, and Australia. ICE-CSIC and IEEC researchers collaborated monitoring data from the New Technology Telescope (NTT) in La Silla (Chile) as part of the ePESSTO+ collaboration. They also monitored the supernova using the camera ANDICAM (A Novel Dual Imaging CAMera), which was mounted on the 1.3-m telescope SMARTS in Cerro Tololo (Chile).

They found that the supernova was running into material previously cast off by one or both stars in the binary system before the white dwarf star exploded. The supernova sent a shock wave into this pre-existing gas. As the researchers monitored the supernova for more than 1,000 days, they noticed that its light began to dim precipitously in the optical wavelengths that our eyes can see, and then started glowing brighter in infrared light. This is a telltale sign that dust was being created in the circumstellar gas after it cooled following the supernova shock wave passing through it.

The study estimated that a large amount of dust must have been created by this one supernova event, more than 1% of the Sun's mass. As the supernova cools down, the amount of dust created should increase, perhaps, tenfold. While these dust factories aren't as numerous or efficient as core-collapse supernovae, there may be enough of these thermonuclear supernovae interacting with their surroundings to be a significant or even dominant source of dust in elliptical galaxies.

Published in Wang, L., et al., incl. **Galbany, L., Müller-Bravo, T. E.** (2024), *Newly formed dust within the circumstellar environment of SN Ia-CSM 2018evt,* Nature Astronomy, 8, 504, 10.1038/s41550-024-02197-9.

Text adapted from the press release published at the ICE-CSIC website.

An artist's depiction of a growing white dwarf star before it goes supernova.
Credits: NASA's Goddard Space Flight Center Conceptual Image Lab.

5.3. A team of ICE-CSIC astronomers discovers three neutron stars too cold for their age

ESA's XMM-Newton and NASA's Chandra spacecraft have detected three young neutron stars that are unusually cold for their age. By comparing their properties to different neutron star models, a team of astronomers led by ICE-CSIC concludes that the oddballs' low temperatures disqualify around 75% of known models. This is a big step towards uncovering the one neutron star 'equation of state' that rules them all, with important implications for the fundamental laws of the Universe.

Matter in the centre of a neutron star is squeezed so hard that scientists still don't know what form it takes. Neutron stars get their name from the fact that under this immense pressure, even atoms collapse: electrons merge with atomic cores, turning protons into neutrons. But it might get even weirder, as the extreme heat and pressure may stabilise more exotic particles that don't survive anywhere else, or possibly melt particles together into a swirling soup of their constituent quarks.

What happens inside a neutron star is described by the so-called 'equation of state', a theoretical model that describes what physical processes can occur inside a neutron star. The problem is, scientists don't yet know which of the hundreds of possible equation of state models is correct. While the behaviour of individual neutron stars may depend on properties like their mass or how fast they spin, all neutron stars must obey the same equation of state.

Digging into data from ESA's XMM-Newton and NASA's Chandra missions, scientists discovered three exceptionally young and cold neutron stars that are 10–100 times colder than their peers of the same age. By comparing their properties to the cooling rates predicted by different models, the researchers conclude that the existence of these three oddballs rules out most proposed equations of state.

The young age and the cold surface temperature of these three neutron stars can only be explained by invoking a fast cooling mechanism. Since enhanced cooling can be activated only by certain equations of state, this allows researchers to exclude a significant portion of the possible models.

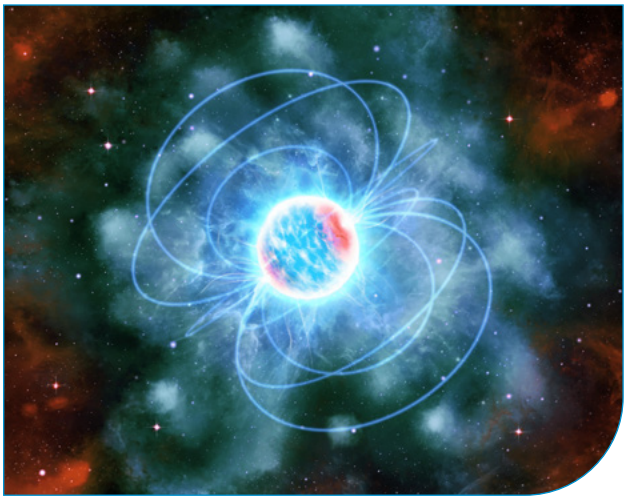
Uncovering the true neutron star equation of state also has important implications for the fundamental laws of the Universe. Physicists famously don't yet know how to stitch together the theory of general relativity (which describes the effects of gravity over large scales) with quantum mechanics (which describes what happens at the level of particles). Neutron stars are the best testing ground for this as they have densities and gravitation far beyond anything we can create on Earth.

The three oddball neutron stars are so cold that they are too dim for most X-ray observatories to detect. However, the sensitive measurements were only the first step towards being able to draw conclusions about what these oddballs mean for the neutron star equation of state.

The team could deduce the temperatures of the neutron stars from the X-rays sent out from their surfaces, while the sizes and speeds of the surrounding supernova remnants gave an accurate indication of their ages. In addition, they computed the cooling curves for a range of possible neutron star masses and magnetic field strengths. Finally, using machine learning to determine how well the simulated cooling curves align with the oddballs' properties, the researchers showed that equations of state without a fast cooling mechanism have zero chance of matching the data.

Published in **Marino, A.**, et al., incl. **Dehman, C., Kovlakas, K., Rea, N., Viganò, D.** (2024), *Constraints on the dense matter equation of state from young and cold isolated neutron stars*, Nature Astronomy, 8, 1020, 10.1038/s41550-024-02291-y.

Text adapted from press release published at the ICE-CSIC website.



An artist's impression of a neutron star, shown as a bright blue and red sphere with spark-like features flying off it. Several blue magnetic field lines loop connect the sphere's two poles. The sphere is surrounded by a see-through blue cloud, and with a red cloud on the sides of the image. Stars are visible in the back-ground.
Credits: ICE-CSIC/D. Futselaar/Marino et al.

5.4. Supermassive black holes detected for the first time in low-mass galaxies at intermediate stages of the Universe

A study led by ICE-CSIC has found supermassive black holes at a key epoch in the history of the Universe called 'Cosmic Noon', about 10 billion years ago, in which star formation and black hole activity reached their peak.

The study reports the finding of active galactic nuclei (AGN) in low-mass galaxies about 10 billion years ago. The main characteristic of these AGN is that they are powered by black holes more massive than expected for the mass of their host galaxies. Being low-mass galaxies, the mass of their black holes is expected to be less than a million times that of the Sun. However, the mass found corresponds to that of supermassive black holes (more than a million times the mass of the Sun), typically hosted in massive galaxies and not in dwarf galaxies.

This finding links for the first time those AGN found in low-mass galaxies at the early Universe by the James Webb Space Telescope with those found in the local Universe. Surprisingly, the properties of the sources, both at the early Universe and Cosmic Noon, are found to be the same in terms of black hole properties, such as mass, luminosity or accretion rate, suggesting that these are the same type of sources but at different cosmic epochs.

The supermassive black holes found in low-mass galaxies are thought to have originated from seed black holes in the early Universe. Hence finding a connection between the local and early Universe can provide a step forward in understanding how these seed black holes formed and evolved.

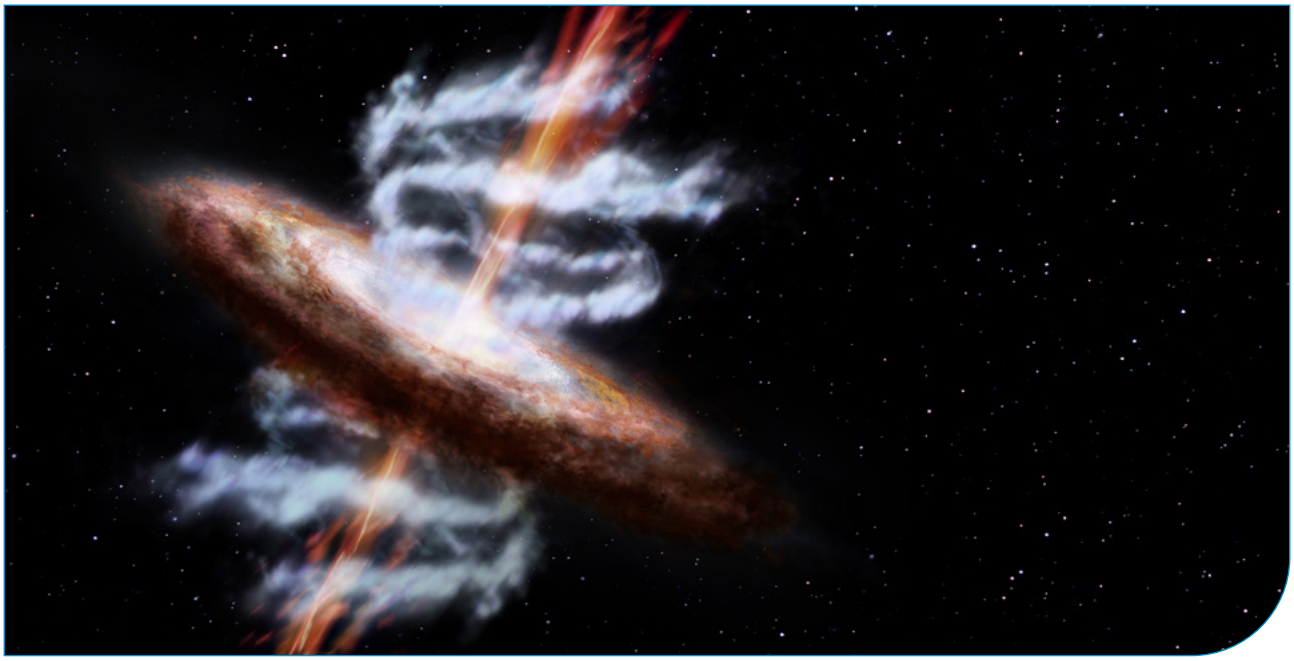
The data used come from public spectroscopic surveys, such as the Sloan Digital Sky Survey (SDSS) located at the Apache Point Observatory in New Mexico (United States of America), the "VIMOS Public Extragalactic Redshift Survey" (VIPERS) from the European Southern Observatory (ESO), as well as published data from the James Webb Space Telescope.

The origins and the mechanisms behind the growth of supermassive black holes remain enigmatic. With cutting-edge telescopes pushing the limits of AGN observational capability we are on the cusp of obtaining more comprehensive insights into black holes and cosmic history. Thanks to synergistic studies of the samples provided by the James Webb Telescope and ground-based telescopes, like VIPERS, we can not only investigate these cosmic phenomena but also shed light on the evolution of galaxies and the formation of our Universe as we know it today.

The team will further investigate the properties of the low-mass galaxies and their black holes at cosmic noon onwards, with the aim of looking for the presence of black hole winds, as well as signatures of galaxy mergers that could shed light on why the black holes are more massive than expected.

Published in **Mezcua, M.**, et al., incl. **Siudek, M.** (2024), *Overmassive Black Holes at Cosmic Noon: Linking the Local and the High-redshift Universe*, The Astrophysical Journal Letters, 966, L30, 10.3847/2041-8213/ad3c2a.

Text adapted from the press release published at the ICE-CSIC website.



Artist's impression of a supermassive black hole in an active galaxy.
Credits: ESA/AOES Medialab.

5.5. Intriguing Earth-sized world discovered

Two international teams of astronomers, including ICE-CSIC researchers, have discovered Gliese 12 b, an exciting planet between the sizes of Earth and Venus only 40 light-years away. The planet is the nearest, transiting, temperate, Earth-size world located to date

Gliese 12 was discovered through a collaboration between NASA's TESS (Transiting Exoplanet Survey Satellite) campaign and a strategic survey programme (SSP) of the Subaru Telescope.

Its host star, called Gliese 12, is a cool red dwarf located almost 40 light-years away in the constellation Pisces. The star is only about 27% of the Sun's size, with about 60% of the Sun's surface temperature. The TESS team detected signs of a planet candidate with a size similar to Earth and reported the detection in April 2023. This report motivated the astronomers to start the follow-up observations for validating the candidate signal with multi-colour cameras. The astronomers were able to constrain the mass of the planet to be less than 3.9 Earth masses by combining measurements taken with Subaru and those with CARMENES on the 3.5 m telescope of the Calar Alto Observatory. Besides CARMENES, the team carried out some observations with the Carlos Sánchez Telescope at the Teide Observatory.

The new world, Gliese 12 b, orbits every 12.8 days and is Earth's size or slightly smaller—comparable to Venus. Assuming it has no atmosphere, the planet has a surface temperature estimated at around 42 °C.

Gliese 12 b represents one of the best targets to study whether Earth-sized planets orbiting cool stars can keep their atmospheres, a crucial step to advance our understanding of the habitability of planets in our galaxy.

The diminutive sizes and masses of red dwarf stars make them ideal for finding Earth-size planets. A smaller star means a greater decrease in brightness each time a planet passes in front of it and a smaller mass means that an orbiting planet can produce a greater wobble, known as "reflex motion", of the star. These effects make smaller planets easier to detect.

The lower luminosities of red dwarf stars also means their habitable zones—the range of orbital distances where liquid water could exist on a planet's surface—lie closer to them. This makes it easier to detect transiting planets within habitable zones around red dwarfs than those around stars emitting more energy.

The distance separating Gliese 12 and the new planet is just 7% of the distance between Earth and the Sun. The planet receives 1.6 times more energy from its star as Earth does from the Sun and about 85% of what Venus experiences.

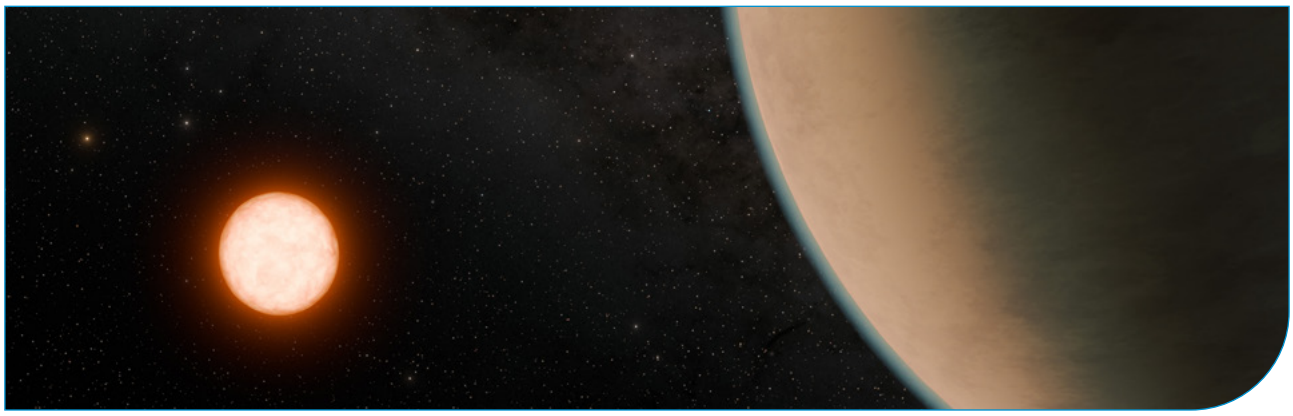
One important factor in retaining an atmosphere is the storminess of its star. Red dwarfs tend to be magnetically active, resulting in frequent, powerful X-ray flares. However, analyses by both teams conclude that Gliese 12 shows no signs of extreme behaviour, which could help preserve the planet's atmosphere.

During a transit, the host star's light passes through any atmosphere, effectively sampling it. Different gas molecules absorb different colours, so the transit provides a set of chemical fingerprints that can be detected by telescopes like Webb.

We know of only a handful of systems to date that are both close enough to us and meet other criteria needed for this kind of study, called transmission spectroscopy, using current facilities. To better understand the diversity of atmospheres around temperate planets similar to Earth, we need more examples like Gliese 12 b.

Published in Kuzuhara, M., et al., incl. **Morales, J. C.**, **Ribas, I.** (2024), *Gliese 12 b: A Temperate Earth-sized Planet at 12 pc Ideal for Atmospheric Transmission Spectroscopy*, The Astrophysical Journal Letters, 967, L21, 10.3847/2041-8213/ad3642.

Text adapted from the press release published at the ICE-CSIC website.



Gliese 12 b, which orbits a cool, red dwarf star located just 40 light-years away, promises to tell astronomers more about how planets close to their stars retain or lose their atmospheres. In this artist's concept, Gliese 12 b is shown retaining a thin atmosphere.
Credits: NASA/JPL-Caltech/R. Hurt (Caltech-IPAC).

5.6. The PAUS survey releases a new cosmic distance catalogue to unlock the mysteries of the Universe formation

The Physics of the Accelerating Universe Survey (PAUS), an international collaboration led by ICE-CSIC, has released a groundbreaking catalogue of cosmic distances. Collected over 200 nights between 2015 and 2019 using the PAUCam camera on the William Herschel Telescope (WHT) in La Palma, this catalogue is now available on the PAUS website and the CosmoHub web portal.

This new catalogue provides information on millions of distant galaxies, determining their distances with unprecedented precision over a field of view and depth never explored before. Covering a vast sky area of 50 square deg^2, similar to an area of approximately 250 full moons, it includes data for 1.8 million astronomical objects. These insights will enable astronomers to create more accurate maps to understand how structure forms in the Universe and to study dark matter and dark energy.

The accelerated expansion of the Universe is attributed to dark energy, which constitutes about 70% of the Universe, yet its nature remains a mystery. The PAUS survey offers new insights into this enigma, providing an accurate and comprehensive characterisation of millions of galaxies up to distances of more than 10 billion light years. This catalogue is a valuable resource for the astronomical community, aiding in the scientific analysis and calibration of other cosmological surveys.

This catalogue represents a significant advancement in cosmic research with its extensive catalogue offering photometric redshift measurements that determine the distances of galaxies as they appeared billions of years ago. To achieve these measurements, the PAU camera employs 40 filters across different colours, representing narrow bands in the optical spectrum. This technique involves photographing the same field multiple times through various colour filters. As objects move away from us, the light they emit experiences a redshift, shifting towards the red end of the spectrum. In astronomy, redshift is crucial for calculating the distance of an object from Earth.

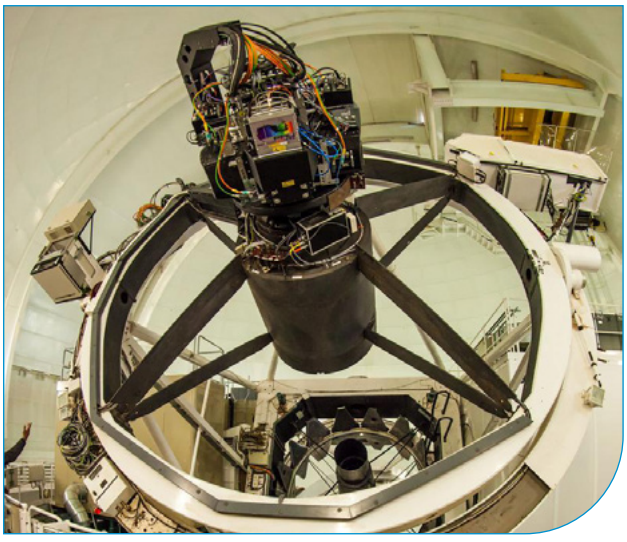
While ongoing and future state-of-the-art spectroscopic cosmic surveys are equipped with large focal planes that enable simultaneous measurement of redshifts for thousands of preselected galaxies—acquiring several hundred galaxy redshifts per square degree in a single observation (out of a total of approximately 30,000 galaxies at the desired depth limit)—the PAUS survey takes a different approach. PAUS does not require preselecting target galaxies. Instead, it utilises its 40 filters to measure the redshifts of all 30,000 galaxies within the field of view at once, albeit with lower spectral resolution.

The PAUS survey provides complete, flux-limited, and highly accurate redshift and spectral energy distribution information for millions of galaxies and stars, reaching a depth and coverage previously unexplored. This is accomplished without the need for specific target selection, offering a powerful tool to better understand sample selection and completeness in astronomical surveys.

Nine years after its first light in 2015, the PAUS survey reached a remarkable milestone, measuring the distances of numerous distant galaxies with a relative precision of 0.3%. The team is currently utilising this data to enhance the calibration of existing cosmological surveys. For instance, PAUS data is being used to improve weak lensing analyses and simulations for dark energy missions such as ESA's Euclid mission and the Rubin Observatory's Legacy Survey of Space and Time (LSST). Additionally, these samples can refine the redshift distributions for such missions, as has already been done for the scientific collaborations Kilo-Degree Survey (KiDS) and the Dark Energy Survey (DES).

Published in (i) **Navarro-Gironés, D.**, et al., incl. **Gaztañaga, E., Crocce, M., Siudek, M., Serrano, S., Casas, R., Castander, F. J.** (2024), *The PAU survey: photometric redshift estimation in deep wide fields*, Monthly Notices of the Royal Astronomical Society, 534, 1504, 10.1093/mnras/stae1686; (ii) **Castander, F. J.**, et al., incl. **Serrano, S., Gaztañaga, E., Casas, R., Alarcon, A., Navarro-Gironés, D.** (2024), *The PAU survey: photometric calibration of narrow band images*, Monthly Notices of the Royal Astronomical Society, 531, 5067, 10.1093/mnras/stae1507.

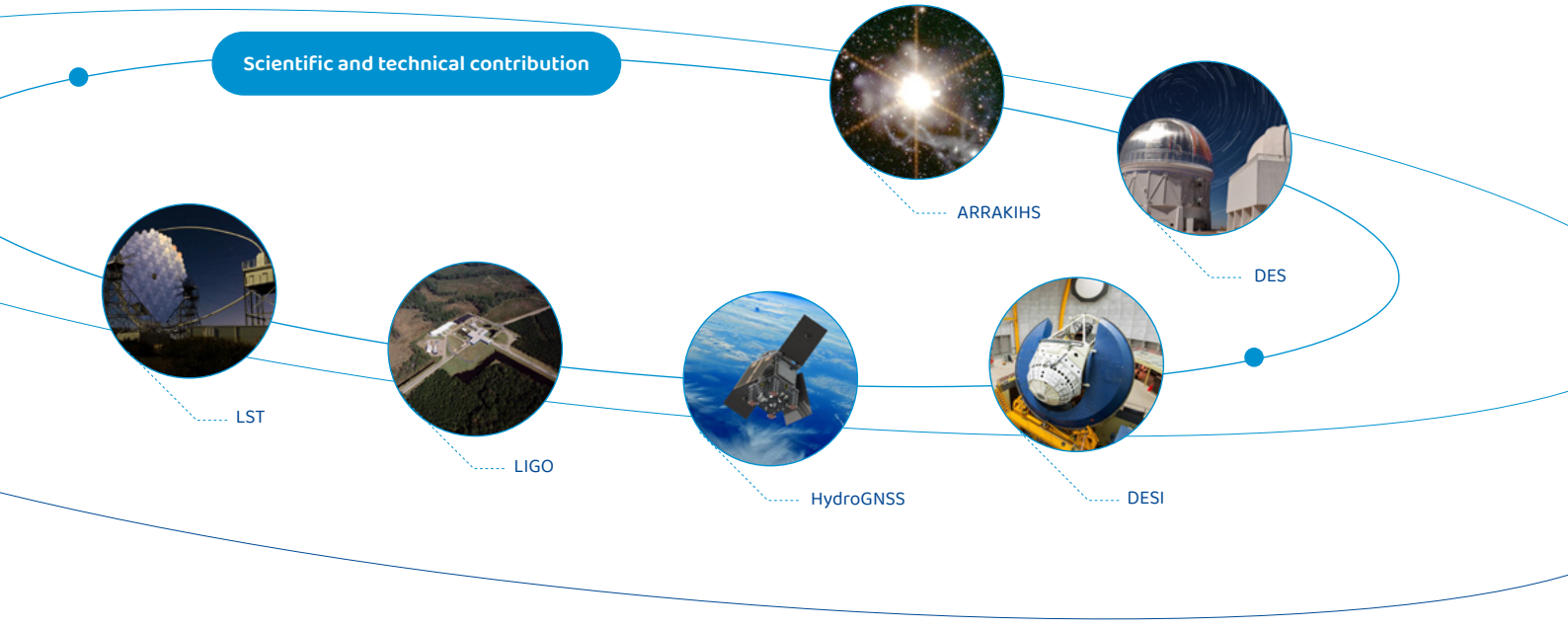
Text adapted from the press release published at the ICE-CSIC website.



PAUcam camera installed in the primary focus of the William Herschel Telescope (WHT) in La Palma, Spain.
Credits: PAUS team.

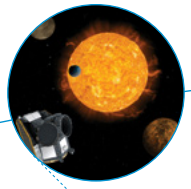
6. Missions and experiments

ICE-CSIC participates in exciting missions and ground-based experiments that have continued this year. In this section, the senior Institute members leading ICE-CSIC contributions to these projects provide a brief description of the focus of their research, together with recent news.



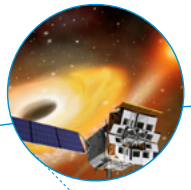
Scientific Contribution

DART



CHEOPS

EINSTEIN TELESCOPE



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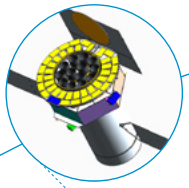

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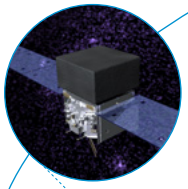

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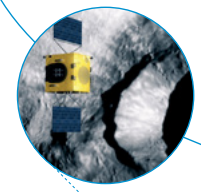

HERA

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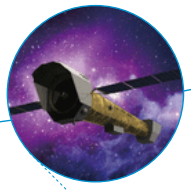


NEWATHENA

ROMAN

SKAO

6.1. Leadership contribution

Space missions, observatories and instruments where ICE-CSIC leads an official contribution.

ARIEL

Senior Institute members involved: I. Ribas, G. Anglada-Escudé, J. C. Morales

Department of Planetary Systems and Earth Observation

Ariel (Atmospheric Remote-sensing Exoplanet Large-survey) is ESA's fourth medium (or "M-class") mission that was adopted in 2020 and is expected to be launched in 2029. It consists of a 1-metre class telescope equipped with low-resolution spectrographs that will cover the wavelength range from 1.1 μm to 7.8 μm. Ariel will study a complete sample of transiting exoplanets by means of transmission spectroscopy. This means that it will measure the spectra of planets through the follow-up of their transit in front of their host stars or the occultations behind them. This type of observation provides a wealth of information about the atmosphere of the planets such as the chemical composition, the vertical pressure-temperature profile, the dayside-nightside temperature difference, the atmosphere circulation patterns, and the presence of clouds for instance. The goal of this survey, which will characterise a large number of exoplanet atmospheres during its 4 years lifetime, is answering the first of the four ambitious topics listed in the ESA's Cosmic Vision: "What are the conditions for planet formation and the emergence of life?".

The ARIEL mission concept is developed by a consortium of more than 70 institutes from 17 ESA countries. ICE-CSIC is one of the co-PI institutes (co-PI: Ribas) and leads the Spanish contribution (PI: Ribas; National Project Manager: Martí), which also includes the Instituto de Astrofísica de Canarias and the Universidad Politécnica de Madrid. The groups at CSIC and at the Universitat de Barcelona, coordinated through IEEC, participate in various aspects of the mission. Among other tasks, the group is responsible for the design, implementation, assembly and verification of the Telescope Control Unit (TCU), which performs the thermal monitoring and control of the telescope and payload module and commands the secondary mirror refocusing mechanism. We are also contributing the mission planning and scheduling software, which is a critical part of the ground segment.

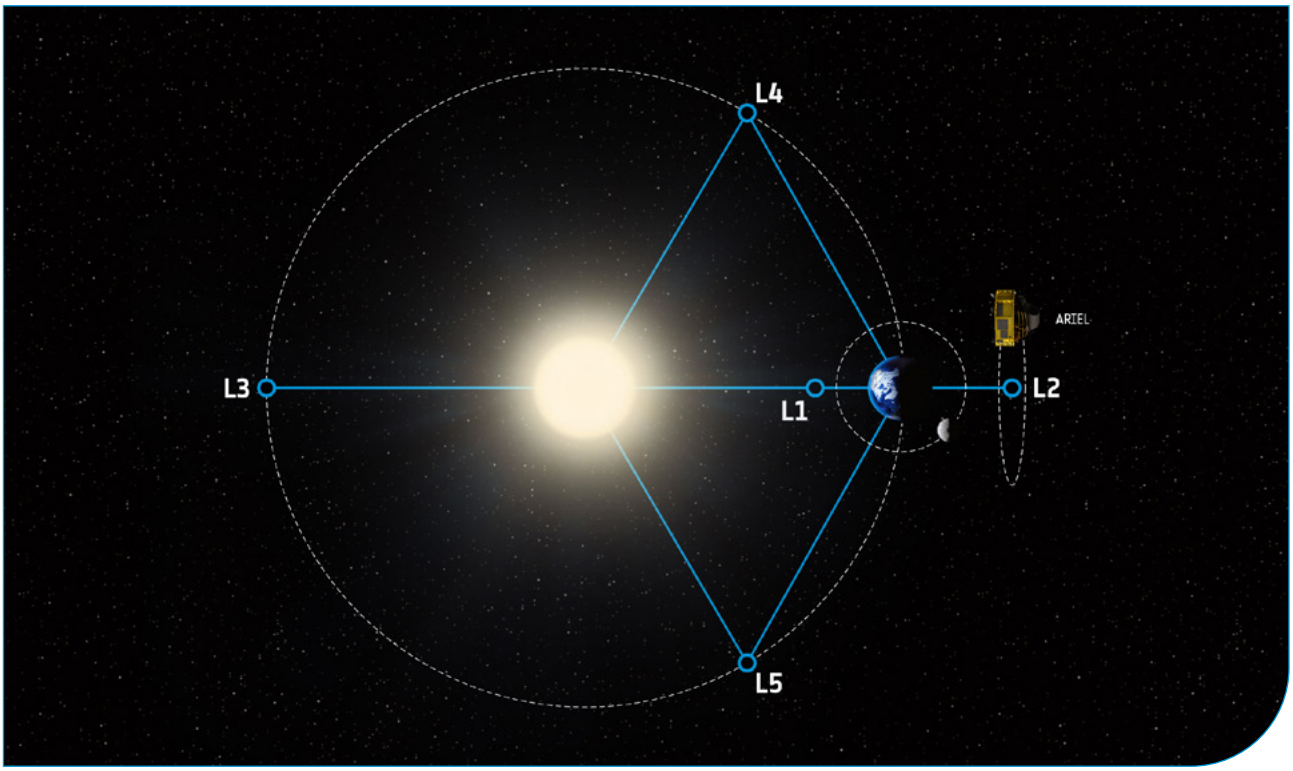


Illustration of Ariel in orbit around the Lagrange Point 2 (L2), a gravitational balance point 1.5 million kilometres beyond the Earth's orbit around the Sun.
Credits: ESA/STFC RAL Space/UCL/Europlanet-Science Office.

Recent developments

Over the past few years, the TCU team has achieved several key milestones on the progress of the unit such as successfully passing the instrument Preliminary Design Review in 2023. This key milestone approved the current design and gave the go-ahead for the main purchase of the necessary components, building and testing of the first units. Further progress has been key in consolidating the final design of the TCU. As a validation, the team manufactured and delivered a structural model in 2024 to Airbus, which was integrated in the platform and underwent mechanical and vibration tests. The design of the different elements that conforms the TCU, such as the power supply unit (PSU), Control and Thermal Sensing (CTS), and the Secondary Mirror Driver (M2MD) have been fully developed and first prototypes are being manufactured to perform interface testing between the TCU and the rest of the teams of the consortium.

Performing observations of a sample of approximately 1,000 exoplanets is a challenging problem. To tackle this, the ICE-CSIC STARS group is developing the Ariel Long Term Planning Tool (LTPT), which is a critical subsystem of the mission Ground Segment (GS). During 2024, the revision of the high-level GS requirements was successfully passed, and the project entered into the design and implementation phase. Releases of the LTPT are being sent periodically to ESA for product assurance evaluation and testing. In addition, a new optimization algorithm based on Swarm Intelligence (Nakhjiri et al. 2024), which significantly improves the efficiency of the LTPT plans, was developed as part of a PhD thesis. Furthermore, a user interface is being implemented to facilitate the production and the visualization of the plans produced by the LTPT.

Regarding science, our work basically consists in studying the effects of stellar intrinsic variations, known as stellar activity, on the spectra of planetary atmospheres. We are developing methods to correct out such variability and thus keep Ariel's data free from any bias. In the past years, we suggested the use of complementary observations for this purpose (see Rosich et al. 2020) and we are implementing this technique to observations of transiting planets with the James Webb Space telescope (JWST; de Wit et al. 2024). We have been conducting pilot observational campaigns to apply the proposed correction methodology, including machine learning, and the results are encouraging. These activities are being performed in the context of three ongoing PhD theses.

CARMENES

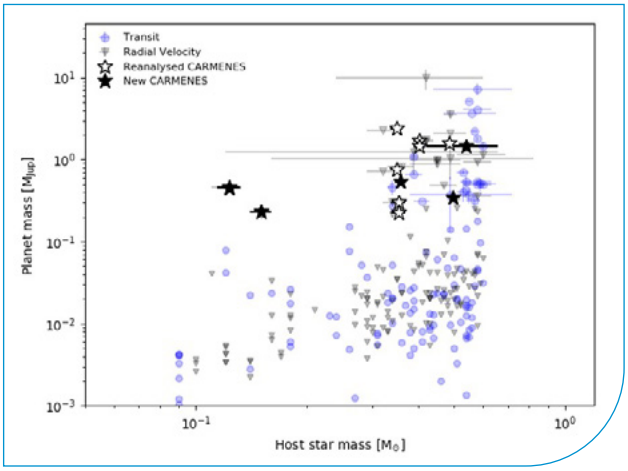
Senior Institute members involved: I. Ribas, J. Colomé

Department of Planetary Systems and Earth Observation

CARMENES (Calar Alto high-Resolution search for M dwarfs with Exoearths with Near-infrared and optical Echelle Spectrographs) is an instrument designed and optimised to look for planets around stars smaller than our Sun.

ICE-CSIC has a prominent role in CARMENES, being responsible for science preparation and exploitation through the figure of the Project Scientist and, more recently, as co-PI of the CARMENES Legacy-Plus project. In this capacity, the ICE-CSIC team leads the selection of the stars that are being searched for planets, the collection of all the necessary information to guarantee the best precision and the analysis of the data acquired to uncover habitable planets.

Besides its scientific role, the ICE-CSIC team was also responsible for key technology packages of the CARMENES spectrograph, which are the Instrument Control System (ICS) and the scheduling system. The ICS is the "brain" of CARMENES and centralises all the subsystems to control the proper working of the instrument, its performance, and environment variables. The scheduler is a complex piece of software factoring in a large number of variables (target properties, prioritisation, environment variables) to find the optimum target to observe at each point in time.



Mass of the exoplanets orbiting around M-dwarf stars discovered by the transit (blue circles) and radial velocity (black triangles) methods as function of the mass of the host star. Star symbols depict systems that have been discovered by CARMENES (filled symbols) or for which CARMENES data allowed to better constrain the parameters of the system.
Credits: CARMENES.

Recent developments

In 2024, the CARMENES survey entered its second extension to look for exoplanets orbiting around M-dwarf stars. The productivity of this project is well proven. This year, more than 15 papers have been published, adding a total of 130 papers from the start of the survey.

Although the discovery of exoplanets is the main goal, CARMENES is also providing a wealth of information to understand the stars and their magnetic activity as well as to discern the components of the exoplanet atmospheres through high-resolution transmission and emission spectroscopy. In the context of planet discoveries, the spectrograph became essential to confirm and measure the masses of planetary candidates coming from the TESS transiting survey.

Besides, it is still discovering planets orbiting the stars for the main survey and demonstrating that the planets around M-dwarf stars are varied. In particular, the ICE-CSIC research group was involved in the detection of a new planet around the very late-type Teegarden's star. This is already the third rocky-planet on this interesting close-by system. On the opposite mass domain, three new long period giant planets around late and early-M dwarfs discoveries were announced at the Exoplanets V conference. The extension of the CARMENES survey is becoming critical to identify the long orbital periods of these systems, which are beyond 6 years.

CTAO

Senior Institute member involved: D. F. Torres

Department of Star formation, Stellar and High-energy Astrophysics

The Cherenkov Telescope Array Observatory (CTAO) is an initiative to build the next-generation ground-based very high-energy gamma-ray instrument. ICE-CSIC has been involved in CTAO since its foundation. On the technical side, we worked in the scheduler team. We have also been involved in preparing the scientific exploitation of the observatory. Concerning the scientific exploitation of the observatory, where our Institute is leading a number of the 'Key Science Programs' (KSPs) putting an effort on maximising the physic output of the CTAO. This follows our earlier efforts where Diego F. Torres has been the CTA Physics Coordinator for eight years in the period 2007-2014, having responsibilities in the scientific definition of the experiment, the KSPs, and up to Technical Design Report. Later on, Emma de Oña, another (former) ICE-CSIC member occupied this post for an additional year.

Recent developments

In September 2024, the CTAO Array Control and Data Acquisition (ACADA) Collaboration achieved a milestone when the CTAO Central Organisation officially approved and closed the Critical Design Review (CDR) of the ACADA system. The approval of the CDR, an in-depth evaluation to ensure the system design meets all the requirements of the observatory, marks a new phase in the project, moving from testing to integrating the advanced software packages that will operate the arrays. ICE-CSIC participates in the ACADA collaboration producing the scheduler software system, and has been directly involved in the CDR, including, in addition to producing the software, in-situ testing at the telescope in La Palma, Spain.

EUCLID

Senior Institute members involved: F. Castander, M. Crocce, P. Fosalba, L. Galbany, E. Gaztañaga, M. Mezcua

Department of Extragalactic Astrophysics and Cosmology

Euclid is an ESA cosmology mission to study the accelerated expansion of the Universe also known as dark energy. ICE-CSIC has leadership roles and visibility in the mission: we belong to the ESA Euclid Science Team, we are part of the Euclid Consortium Board, we lead the simulation effort, we develop software and have contributed to hardware development.

Euclid's new image of star-forming region Messier 78.
Credits: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi; CC BY-SA 3.0 IGO or ESA Standard Licence.

Recent developments

At the end of 2023 and the beginning of 2024, Euclid performed the Phase Diversity Campaign to measure the Wide Front Error and calibrate the system point spread function (PSF). On 14 February, Euclid started the observations of its wide survey. The transmission of the telescope was gradually degrading due to ice accumulation on the optical system and the project decided to stop the survey operations to de-ice the telescope. In March 2024, the two optical elements, the third mirror M3 and the third folding mirror FOM3 were warmed up to sublimate the ice. The transmission was recovered to previous levels and the survey continued. However, the transmission started to degrade again at a faster pace than before. The project decided to stop the survey and warm the FOM3 mirror in June 2024. Again, the transmission was recovered and the survey continued. Since this second decontamination procedure the transmission has not degraded. On 23 May 2024, the Early Release Observations (ERO) were publicly released. Together with the ERO data release, five Euclid papers and ten ERO papers were submitted to *Astronomy & Astrophysics* (A&A). The survey has routinely continued since the second decontamination campaign. From time to time solar flares degrade the quality of the images taken, as the strong flux of high-energy particles hit the detectors.

The Science Ground Segment has been extremely busy trying to keep up with the data reduction. In October the capabilities of Euclid were presented by the ESA Science Director at the Milano International Astronautical Congress. In November, the Q1 data were internally released to the collaboration. Q1 data will be publicly released in March 2025. The Key Projects for the First Data Release have been defined and the coordinators selected through an open call.

On ICE-CSIC's side, we continued to lead the Cosmological Simulations working Group and the Simulations Organisation Unit of the Science Ground Segment. We finished the Flagship simulation and submitted the paper to A&A in May 2024. This paper is now accepted and it is intended for a Euclid Special Issue of the A&A journal. We are now working on preparing for the simulations needed for the scientific analysis of the Data Release 1 (DR1). The paper describing the eight simulations of the Science Challenge has already been published. We are now also coordinating the DR1 Key project in charge of computing the cosmological constraints from the joint analysis of the weak lensing and galaxy clustering results. The Euclid Consortium Board decided to choose Barcelona as the host of the Euclid Consortium meeting in 2026.

LISA

Senior Institute members involved: C. Sopuerta, M. Nofrarias, S. Husa

Department of Nuclear, Gravitational Wave and Multi-messenger Astrophysics

LISA is a mission concept proposed by the LISA Consortium in 2017 following the call for the L3 mission of the European Space Agency. LISA's goal is to fulfil the science presented in the white paper 'The Gravitational Universe', approved by ESA in 2013, consisting of low-frequency gravitational-wave astronomy. ICE-CSIC's Gravitational Astronomy Group leads the Spanish contribution to the LISA mission and has led the Spanish contribution to the precursor technology demonstration mission, LISA Pathfinder, which successfully concluded in 2017. The group's contribution to LISA is the Data and Diagnostics Subsystem, which consists of the mission payload computer along with all the corresponding software (both operating system and applications software). The Diagnostics Subsystem consists of a series of sensors and actuators of high precision and unprecedented stability, together with all the associated electronics.

Members of the LISA Consortium Constitutional Council held on 15 April 2024.
Credits: Carlos F. Sopuerta.

Recent developments

In 2024 LISA officially became a mission of the ESA Scientific Programme. It successfully passed the so-called Mission Adoption Review, which marks the end of the design phase and the initialisation of the industrialisation phase. The ICE-CSIC team (Miquel Nofrarias is the PI leading this effort) has been actively supporting ESA in the definition of the Science Diagnostics Subsystem (SDS) —the Spanish contribution to the mission— both in terms of prototype development and the production of all required documents to bring the system to a reality. The ICE-CSIC team is involved in the mission definition and, also, in the industrialisation of the SDS through a PRODEX contract with SENER Aerospacial company.

In 2024 the ICE-CSIC team members got involved in the development of ILIADA (In-Orbit LISA Diagnostics Demonstrator), a technology demonstrator selected to fly in the GENEO-02 CubeSat, the forthcoming satellite promoted within the NewSpace strategy from Generalitat de Catalunya with an expected launch in 2026.

On the science exploitation side (Carlos F. Sopuerta is the PI leading this effort), ICE-CSIC is going to lead the Spanish contribution in the form of a Data Distributed Centre, as part of the LISA Data Distributed Processing Center (DDPC), together with a so-called global fit pipeline that will create a catalogue of gravitational sources from the LISA Data stream. In addition, thanks to the incorporation of Sascha Husa to the group, we also now have an important contribution to the development of waveform models in the context of the DDPC, which are crucial for the global fit pipeline to produce reliable scientific results.

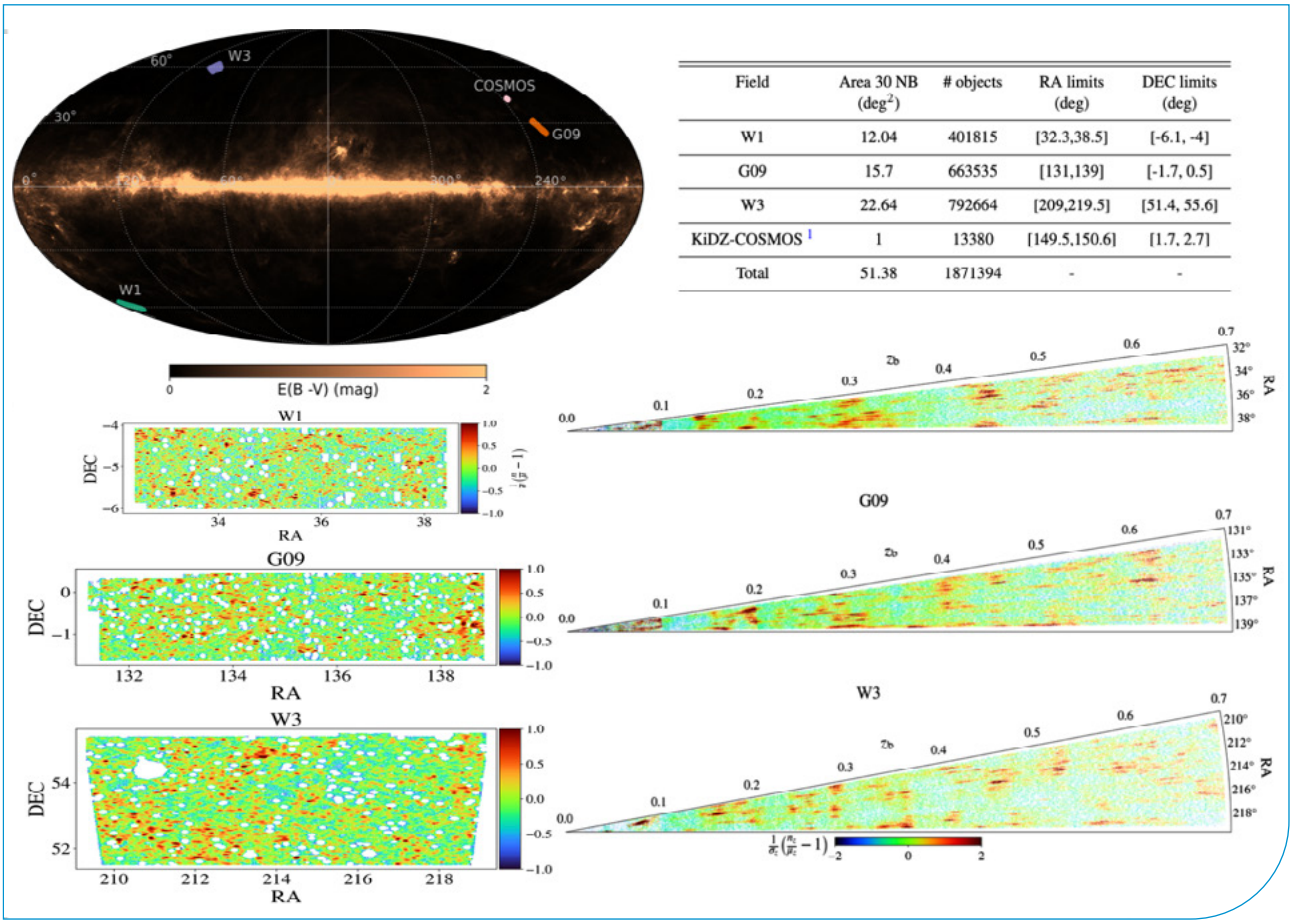
In 2024, ICE-CSIC organised and hosted the first LISA Spain meeting with the objective to gather the scientific community. Around 100 scientists from 27 different research institutions attended the meeting.

PAU

Senior Institute members involved: E. Gaztañaga, F. Castander, M. Crocce, P. Fosalba

Department of Extragalactic Astrophysics and Cosmology

PAUcam is a unique instrument designed to make high accuracy photometric surveys using 40 narrow-band filters spaced by 100Å in the spectral range of 4500-8500Å. Together with IFAE, we are responsible for building and maintaining the PAUcam in the 4m WHT Telescope in La Palma, Spain. ICE-CSIC is leading the Science and operation of the PAU Survey (PAUS). We also manage the international collaboration and data reduction.



Field	Area 30 NB (deg^2)	# objects	RA limits (deg)	DEC limits (deg)
W1	12.04	401815	[32.3,38.5]	[-6.1, -4]
G09	15.7	663535	[131,139]	[-1.7, 0.5]
W3	22.64	792664	[209,219.5]	[51.4, 55.6]
KiDZ-COSMOS [1]	1	13380	[149.5,150.6]	[1.7, 2.7]
Total	51.38	1871394	-	-

Left: Fluctuations in the mean number of observed galaxies (normalised in units of the rms σ) projected in the 2D sky.
Right: same fluctuations as function of the 3D radial distance (photometric redshift, zb, or lookback time).
Credits: Navarro-Girones et al. (2024) and Daza-Perilla et al. (2024).

Recent developments

In 2024, PAUS achieved significant milestones, including the publication of several key collaboration papers. These covered topics such as photometric calibration, galaxy formation models, galaxy stellar population properties, photometric redshift errors, and quasar UV and Lyman-alpha luminosity functions.

A major highlight of the year was the main public data release. This release made available data for over 1.8 million objects observed over 200 nights from 2015 to 2019, utilising the 4.2-meter William Herschel Telescope (WHT) in La Palma, Spain. The dataset is one of the most precise in its class, leveraging PAUS's unique photometric system of 40 narrow bands to enable highly accurate photometric redshifts and the detailed study of galaxy properties.

These efforts represent a significant contribution to our understanding of galaxy formation and evolution, further solidifying PAUS' role as a leader in advancing precision photometry and its applications in cosmology and astrophysics.

PAZ

Senior Institute members involved: E. Cardellach, R. Padullés, S. Ribó, A. Rius

Department of Planetary Systems and Earth Observation

The Radio Occultation and Heavy Precipitation aboard PAZ (ROHP-PAZ) is a proof-of-concept experiment designed and managed at ICE-CSIC. The polarimetric radio occultation measurement concept was conceived at the Institute to measure atmospheric heavy precipitation in addition to the standard radio occultation thermodynamic products. The novelty of the Radio Occultation and Heavy Precipitation experiment aboard PAZ, launched in February 2018 and activated in May 2018, is its capability to quantify the effects suffered by the signals induced by large rain droplets (intense rain) and frozen particles (cloud ice, snow, graupel, etc.). Thanks to the ROHP-PAZ data, ICE-CSIC researchers have confirmed the experiment's hypothesis: the recorded polarimetric signals are sensitive to heavy rainfall and other hydrometeors.

These features are captured through the vertical and horizontal components of the GPS signal, the so-called 'polarimetric observations', measured for the first time from space. The experiment is also the only one able to jointly sense precipitation and its thermodynamic properties, important pieces of information to understand the conditions underlying intense precipitation, with potential to contribute to improving the modelling/ forecast/ climate projections of these extreme events. The polarimetric data are accessible through the ROHP-PAZ website, hosted at ICE-CSIC, which also contains outreach information. The ROHP-PAZ experiment is an experiment funded by the Spanish Ministry of Science and Innovation, and led by ICE-CSIC. In addition to NASA Jet Propulsion Laboratory, the experiment is possible through collaborations with the PAZ satellite owner, operator and exploiter, Hisdesat, the National Oceanic and Atmospheric Administration and the University Corporation for Atmospheric Research. The 'traditional' (equivalent to non-polarimetric) radio occultation data are disseminated in near-real time to worldwide weather services through the WMO/UN Global Telecommunications System.

Recent developments

During 2024, ROHP-PAZ continued to provide with GNSS polarimetric radio occultation data (GNSS PRO), and ICE-CSIC has processed the data into calibrated vertical profiles of polarimetric phase shift. New algorithms have been used to re-process the whole mission, to provide a new type of product called Research Profiles. A DOI has been assigned to this new type of product. Furthermore, scientific and operational interest has risen in the last year, with a second commercial company launching a satellite with PRO capabilities, and the community issuing a document, a roadmap to guide the agencies towards full exploitation of this technique. This document was led by ICE-CSIC researchers.

PLATO

Senior Institute members involved: I. Ribas, A. Serenelli, J. C. Morales

Department of Planetary Systems and Earth Observation

Plato (PLAnetary Transits and Oscillations of stars) is the next ESA medium-class mission to be launched in 2026. It consists of 26 cameras that will be staring continuously to a 49x49 deg field on the sky, with the goal of detecting the transits of exoplanets crossing in front of their host stars, and in particular, a Sun-Earth twin. The exoplanets detected by Plato will have to be confirmed with additional photometric and high contrast imaging observations in order to discard false positive scenarios as well as with spectroscopy to provide a measurement of the mass of the exoplanet.

The Ground-based Observations Program (GOP) will be in charge of coordinating all these observations. The exoplanet candidates received from the PLATO Data Centre will be distributed among the different facilities according to the relevant parameters and to the observing time availability. At ICE-CSIC, in collaboration with a broader IEEC team, we are contributing to the GOP with a planning software based on the STARS scheduling tools and Artificial Intelligence optimization algorithms that we are developing.

Recent developments

During 2024, the Requirements and Design review was passed, and we started implementing the prototype of the Plato-GOP scheduler in order to be ready for the GOP testing campaign expected early in 2025. Besides, we are adapting the STARS graphical user interface to the Plato case.

In addition to participating in the GOP, ICE-CSIC is helping to better define the science case of the mission and contributing to the preparation of the data analysis tools. We have been actively participating in the work packages on Stellar Activity and Rotation and Spot Models and we are responsible for the production of the libraries of stellar models that will be used by Plato to determine the fundamental properties of stars in its core programme.

6.2. Scientific and technical contribution

This section comprises missions where ICE-CSIC provides important contributions to the development of space missions and instruments.

ARRAKIHS

Senior Institute members involved: R. Casas, F. Castander, P. Fosalba, E. Gaztañaga, M. Montes, S. Serrano

Department of Extragalactic Astrophysics and Cosmology

ARRAKIHS (Analysis of Resolved Remnants of Accreted Galaxies as a Key Instrument for Halo Surveys) is a space mission that was selected in November 2022 as the new fast mission in ESA's Science Programme. ARRAKIHS is designed to study the effects of dark matter on the observed galactic structures exploring the low surface brightness regime. ARRAKIHS will image about one hundred nearby galaxies and their surroundings, using innovative twin binocular assemblies of small telescopes, to characterise the number and nature of galactic substructure and stellar streams in their vicinity. This survey, in visible and infrared wavelengths, will far exceed what is currently possible from ground-based telescopes and will provide the possibility to make tests of the dark matter paradigm of structure formation as well as producing a dataset of significant legacy value.

Recent developments

In 2024, the ICE-CSIC and the IEEC team made important contributions to the ARRAKIHS mission, particularly in technical development, scientific studies, and mission preparation. The team played a key role in successfully passing two major instrument reviews, the Preliminary Requirements Review in February and the System Requirements Review later in the year. These milestones marked the completion of Phases A and B1 in record time.

ICE-CSIC also contributed to the PRODEX Dicryoguide project, working alongside IFCA and Satlantis. The team focused on the performance analysis and simulation of the Fine Guidance System for the ARRAKIHS instrument. Additionally, the engineering team began planning the main characterisation site for the visible detectors in its laboratory facilities, joining the detector task force at ESA ESTEC.

Throughout the year, the team participated in the two mission consortium meetings in Sweden and Switzerland and contributed to preparatory activities at the ESA Science Study Team for the mission's "Red Book," required for adoption in 2026. The ICE-CSIC team is also engaged in key scientific activity on cosmological simulations, low surface brightness, and cirrus studies.

DES

Senior Institute members involved: E. Gaztañaga, F. Castander, M. Crocce, P. Fosalba, L. Galbany

Department of Extragalactic Astrophysics and Cosmology

The Dark Energy Survey (DES) is an international astronomical collaboration with more than 400 scientists from 25 institutions. The DES collaboration designed, built and operated a state-of-the-art imaging camera (DECam) to produce the largest survey of galaxies in the Universe, more than 500 million objects over 5000 deg^2 of the southern sky, and spanning the last 10 billion years of cosmic history. The goal is to trace the large-scale structure of the Universe to study some major issues in observational cosmology, in particular the late time cosmic acceleration. DES last observations were in January 2019 while the collaboration is now concluding the final science analysis with the full dataset, probing the growth of structure by combining clustering and lensing, in addition to baryon acoustic oscillations (BAO), Type Ia supernovae (SNIa), and clusters.

DES Collaboration meeting at S'Agaró (Spain) in May 2024.
Credits: Judit Prat.

Recent developments

Since the publishing of the cosmological results from the analysis of the 3rd year of observations (DES-Y3) in summer 2021, the collaboration has been actively working towards the completion of its last cosmological analysis, with data catalogues built from the full six years of observations. In 2024, the Supernovae group completed an analysis to constrain the expansion rate of the Universe using 1,500 new high redshift SNIa photometrically identified. This dataset is several times larger than any previous SNIa compilation at redshift > 0.5. The results, showing consistency of the Lambda cold dark matter model (DES Collaboration, Abbott et al. 2024), have had a huge media impact, e.g. dozens of news articles, and a number of fairly high profile interviews. When combined with the recent first-year DESI results, they represent some of the strongest evidence to date for the potential existence of evolving dark energy. In turn, the BAO analysis (Abott et al. 2024) was also finalised incorporating 50% more galaxies, which improved constraining the power on the distance to redshift of about 1 by 25% with respect to the Y3 analysis. Lastly, the results from the main galaxy catalogue for cosmology, DES Y6 Gold, are already public (Bechtol et al. 2025), with nearly 450 million galaxies ready for cosmology. The final analysis of weak lensing and galaxy clustering using this catalogue is around the corner, with the results for cosmology expected by early 2025. These results incorporate over 20-30% more galaxies and better control of systematics, thanks to the higher depth of DESY6 data. The cosmology group at ICE-CSIC is leading and contributing to different parts of this comprehensive analysis, with Martin Crocce as Key Project coordinator and Alex Alarcon as Redshift Working Group convener. Furthermore, ICE-CSIC organised the DES collaboration meeting in S'Agaró in May 2024, bringing together over 100 researchers from around the world.

DESI

Senior Institute members involved: F. Castander, M. Crocce, P. Fosalba, E. Gaztañaga, M. Mezcua

Department of Extragalactic Astrophysics and Cosmology

The Dark Energy Spectroscopic Instrument (DESI) collaboration has built a large field of view multi-fibre spectrograph to perform a spectroscopic survey of tens of millions of galaxies to study dark energy using baryon acoustic oscillations (BAO) and redshift space distortions. ICE-CSIC, together with IFAE, has built the guiding and focusing of the Guiding, Focusing and Alignment system (GFAs) units of the instrument. ICE-CSIC also developed the guiding software. We also lead the Image Validation Working Group and participate in the collaboration management in the institutional board, and membership committee.

Recent developments

In 2024, DESI completed its third year of observations. Operations have continued routinely. DESI has now gathered around 50 million spectra of galaxies and quasars and around 15 million spectra of stars. DESI is ahead of schedule and plans are being made for an extension of the survey with further passes in bright and dark time and also an extension of the survey area. Plans are also underway to study the possibility of a second part of the DESI survey, focusing on higher redshift tracers of the large scale structure. The BAO Year 1 results were made public in April 2024 at the American Physical Society and Moriond conferences with an accompanying press release. The results hint to an evolving equation of state of the dark energy parameter. These results have prompted a lot of activity in the cosmological community. As a result, the DESI Y1 BAO results paper has been the most cited paper in 2024. In November 2024, several key project papers were submitted for publication including the cosmological results from the full shape analysis of the measured power spectrum of all the tracers. In September 2024, the Y3 internal data release was distributed to the collaboration. In December 2024, the analysis of the BAO Y3 data was unblinded during the DESI collaboration meeting.

Our ICE-CSIC group continues to be involved in DESI management, with Francisco Castander acting as deputy chair of the institutional board and Malgorzata Siudek acting as coordinator of the Galaxy and Quasars Physics Science Working Group. In terms of science developments, we have continued with our involvement in the galaxy clustering, galaxies and quasars, and Clustering, clusters and cross-correlation science working groups; and participated in some secondary programmes.

HydroGNSS

Senior Institute members involved: E. Cardellach, S. Ribó, A. Rius, W. Li

Department of Planetary Systems and Earth Observation

HydroGNSS is the second ESA's Scout mission. The HydroGNSS mission, led by the British company Surrey Satellite Technology Ltd, will provide measurements of key hydrological climate variables including soil moisture, freeze–thaw state over permafrost, inundation and wetlands, and above-ground biomass.

In order to obtain these measurements, scientists use a technique called 'Global Navigation Satellite System (GNSS) reflectometry'. HydroGNSS paves the way for an affordable future constellation that can offer measurements with a temporal-spatial resolution not accessible to traditional remote sensing satellites, thus offering new capacity to monitor very dynamic phenomena and helping to fill the gaps in our monitoring of the Earth's vital signs for the future.

Recent developments

After the selection and approval by ESA of the mission in 2021, ICE-CSIC's Earth Observation Group has intensively worked as part of the mission consortium towards a quick implementation. The group is responsible for the development, implementation and validation of the operational level-1b processors for signal coherence detection, the level-2 surface inundation processor (operational algorithms for surface water detection), and the 'coherent channel' simulator module, a new mode of the GNSS reflectometry receiver to be tested in HydroGNSS, whose exploitation is also responsibility of the ICE-CSIC researchers. All these algorithms and processors were already provided to the prime contractor in 2023 and are part of the operational Payload Data Ground Segment of the mission. During 2024, the Earth Observation Group has conducted their final validations before launch, expected by October 2025.

LIGO

Senior Institute member involved: S. Husa

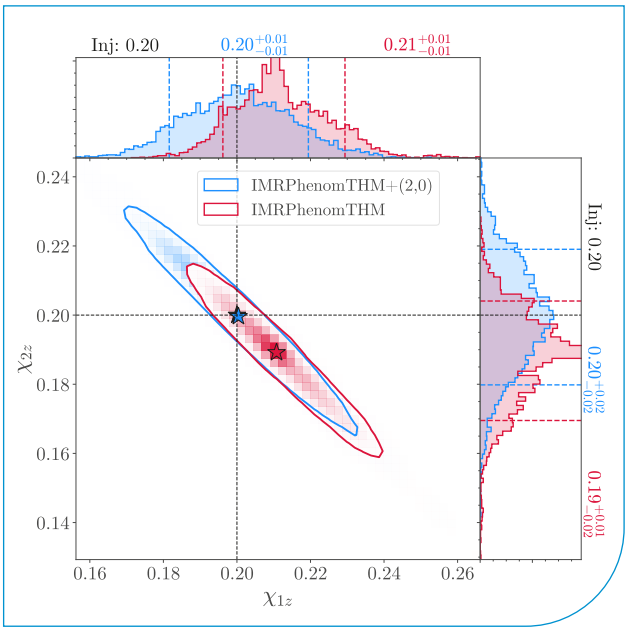
Department of Nuclear, Gravitational Wave and Multi-messenger Astrophysics

The Laser Interferometer Gravitational-Wave Observatory (LIGO) is a groundbreaking scientific facility designed to detect and study gravitational waves, which has opened a new window into the cosmos, allowing scientists to explore phenomena such as black hole mergers, neutron star collisions, and other powerful astrophysical events.

LIGO made its first detection of gravitational waves, generated by a pair of colliding black holes some 1.3 billion light years away, in 2015.

LIGO operates two large-scale interferometers in the United States of America. These observatories use laser light and precisely aligned mirrors to detect minute distortions caused by passing gravitational waves. By measuring these disturbances, LIGO provides direct evidence of Einstein's theory of general relativity and unveils information about events billions of light-years away.

ICE-CSIC participates in LIGO through ICE-CSIC researcher Sascha Husa and his affiliation to the Universitat de les Illes Balears (UIB) Gravitational Physics Group, which is a member of the LIGO Scientific Collaboration (LSC). Husa is leading a team that develops computationally efficient codes for waveform models, which have been used by the LIGO-Virgo-KAGRA collaboration to analyse all events detected to date. Husa is also a member of the Council of the LSC.



The image shows the measured posterior distributions for the component spins of a merging black hole binary as it would be seen with the LIGO detectors after their next upgrade. The probability distribution that would be measured when the memory effect and is not taken into account is shown in red, and in blue the image shows the shifted results that would be measured when the spherical harmonic content of the signal also takes into account the mode that contains the memory.
Credits: Maria Rosselló-Sastre (UIB) and Sascha Husa, unpublished.

Recent developments

After a long period of upgrades to the LIGO detectors since 2020, in 2024, the LIGO detectors have been carrying out the fourth observation run (which started in 2023 and will continue until late 2025). During this time routine analysis has been carried out with computationally efficient waveform models that ICE-CSIC member Sascha Husa has co-developed. The main activity of Husa during 2024 was to work toward upgrades of these models toward the requirements in terms of accuracy and computational efficiency for the next (fifth) observation run of LIGO (to be carried out jointly with the Virgo and KAGRA detectors).

This work has concerned in particular the development of waveform models that include the "memory effect"— a component of the gravitational wave signal that leaves behind a persistent change in the length of the interferometer arms after the transient signal has passed. This component is hard to model and hard to observe, but will be crucial in future tests of general relativity and to improve the measurement of the distance of gravitational wave signals. This work has led to three publications co-authored by Husa (Xu et al.2024; Rosselló-Sastre et al. 2024; Valencia et al. 2024). Husa has also co-authored a paper with two doctoral students he supervises at UIB, which improves the modelling of the influence of the black hole spins during the merger of two black holes on the properties of the remnant black hole.

In addition, Husa has worked on the modelling of the gravitational wave signal emitted by merging binaries with orbital eccentricity. A paper will be published in early 2025, which for the first time will reduce the computational cost of Bayesian inference with eccentric waveform models to allow the routine use of such models in the analysis of observed events. Discovery of orbital eccentricity in merging compact binaries would be a clear marker of the dynamical formation of such binaries, e.g. in dense globular clusters. Husa has also acted as co-chair of the internal review within the LIGO Scientific Collaboration of a new code that interfaces waveform models with data analysis codes, and based on his contributions to the LIGO Scientific Collaboration he remains a co-author of all collaboration publications.

LST

Senior Institute member involved: D. F. Torres

Department of Star Formation, Stellar and High-energy Astrophysics

The Large Sized Telescope (LST) is one of the key components of the CTAO, the first open ground-based gamma-ray observatory and the world's largest and most sensitive instrument for the exploration of the high-energy Universe. Designed to detect gamma rays in the energy range of 20 to 150 GeV, the LST provides critical data on transient and distant gamma-ray sources such as pulsars, black holes, and supernova remnants.

Four LSTs will be arranged at the Roque de los Muchachos Observatory in La Palma, Spain. The LST-1 is the prototype of the LST, currently under commissioning. Each LST is a giant 23 metre diameter telescope with a mirror area of about 400 square metres and a fine pixelised camera made of 1855 light sensors capable of detecting individual photons with high efficiency. The LST Collaboration comprises over 400 scientists and engineers from 12 countries, ensuring global expertise and innovation.

LST-1 telescope with starry sky in the background.
Credits: IAC / Daniel López.

Recent developments

In 2024, ICE-CSIC participated in several proposals for the latest LST observation cycle with approximately 500 hours available. All of them were supported by the Galactic working group from the LST Collaboration, and three obtained guaranteed observation time amounting to 145 hours granted in total. More concretely, two of the proposals were dedicated to observing new PeVatron candidates that were recently detected with the Large High Altitude Air Shower Observatory (LHAASO), i.e., 1LHAASO J1906+0712, and 1LHAASO J056+6346u. ICE-CSIC also participated in a proposal to detect the relativistic jets of the microquasar V4641 with the LST. LHAASO J1906+0712 was observed for the full 50 hours requested in 2024, and the collected data was analysed at ICE-CSIC, as lead researchers. In addition, ICE-CSIC participated in the operations of the LST-1 in the Observatorio del Roque de los Muchachos (La Palma), with two operators working onsite for an entire observing period of 21 days between May and June 2024.

6.3. Scientific contribution

ICE-CSIC members are part of the scientific teams involved in the space missions and observatories.

CHEOPS

Senior Institute member involved: I. Ribas

Department of Planetary Systems and Earth Observation

The CHaracterizing ExOPlanet Satellite (Cheops) is the first mission dedicated to studying bright, nearby stars that are already known to host exoplanets, in order to make high-precision observations of the planet's size as it passes in front of its host star. The Cheops mission was launched in December 2019 and it has been on nominal operations since April 2020. The 30-cm telescope is designed to observe a large sample of transiting exoplanets, and to excel at the measurement of the tiny imprint of the planet on the transit and eclipse events, with a precision never attained before.

ICE-CSIC is involved in the scientific aspects of the Cheops mission through its participation in the Mission Board and Core Science Team. In addition, the mission control team employs our schedule visualisation tool to allow mission planners evaluate the plans produced by the scheduling algorithm and detect possible alternatives for optimisation.

Recent developments

During 2024, Cheops produced a large number of publications, totalling 23 in top-tier refereed journals, which include several highlights where our Institute is involved. A particularly prominent example is the work (Demangeon et al. 2024) presenting observations of the phase curve, transits and occultations of the exoplanet WASP-76 b, which has been proposed to have an asymmetry between the two limbs. Cheops observations suggest that the planet could have night-side clouds that extend predominantly towards its eastern limb. At this limb, the clouds would be associated with spherical droplets, which would be responsible for a glory effect. Another relevant publication is the report of the in-orbit Cheops performance (Fortier et al. 2024), which demonstrates the success of the mission by meeting or exceeding the design requirements and provides plenty of information to help researchers make optimal use of the data.

DART

Senior Institute member involved: J. M. Trigo-Rodríguez

Department of Planetary Systems and Earth Observation

NASA's Double Asteroid Redirection Test (DART) is the first kinetic impact mission dedicated to demonstrating the method of asteroid deflection in a Potentially Hazardous Asteroid. On 22 September 2022, the DART spacecraft collided with asteroid Dimorphos, a 160 metres-in-diameter satellite of the four times larger asteroid Didymos. DART changed successfully the orbit of Dimorphos within the binary system.

Recent developments

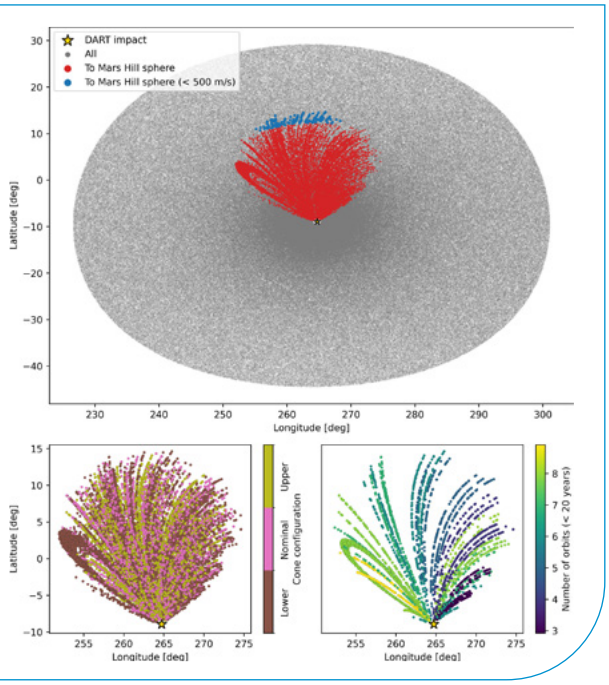
During 2024, the ICE-CSIC Asteroids, Comets and Meteorites research group continued several tasks associated with their involvement in DART.

J.M. Trigo-Rodríguez participated in the analysis of the largest rocks found in the surfaces of Didymos and Dimorphos to find out the main physical processes sculpting them. One of the studies quantified macro-scale roughness to exemplify the complex history of asteroids Didymos and Dimorphos (Vicent et al. 2024). Other works concentrated in the geology of Didymos, being affected by close encounters with its satellite Dimorphos that reshaped the structure and surface of both rubble piles (Barnouin et al. 2024; Pajola et al. 2024).

Finally, a study led by former ICE-CSIC PhD student Eloy Peña-Asensio investigated the delivery of DART's impact ejecta to other celestial bodies. The work was published in *The Planetary Science Journal* and compiled dynamical simulations of ejecta into three distinctive size populations: 10 cm, 0.5 cm, and 30 μm (Peña-Asensio et al. 2024). The simulation was constrained using postimpact observations

-obtained by LICIACube- of the impact plume and the material released from Dimorphos' surface. The main simulation explored ejecta velocities ranging from 1 to 1000 m/s, while a secondary simulation focused on faster ejecta with velocities from 1 to 2 km/s. As a result, some DART ejecta orbits were compatible with the delivery of meteor-producing particles to Mars and Earth, although in tiny proportions. There is a possibility of ejecta reaching the Mars Hill sphere after 13 years from DART's impact for those particles with launch velocities around 450 m/s.

That work also found that some ejecta particles launched at 770 m/s could potentially reach Mars' vicinity in 7 years. Faster ejecta resulted in a higher flux delivery toward Mars and particles impacting the Earth Hill sphere above 1.5 km/s. We found that the transport up to Mars is sensitive to the initial observed cone range. The launch locations for material delivery to Mars were predominantly north of the DART impact site, while they displayed a southwestern tendency for the particles reaching Earth–Moon system. This study was highlighted by ESA and other space media, and provided comprehensive information to forecast future meteor showers on Earth associated with DART's impact on Dimorphos.



Ejecta launch locations of particles delivered to Mars in the Dimorphos body-fixed frame for the main simulation group by particles that were launched above and below 500 m/s (top), by cone configuration (bottom left), and by the number of orbits preimpact for the first 20 years (bottom right).
Credits: Peña-Asensio et al. (2024).

EINSTEIN PROBE

Senior Institute member involved: N. Rea

Department of Nuclear Astrophysics, Gravitational Wave Astronomy and Multi-messenger Astrophysics

The Einstein Probe is an X-ray astronomical space mission led by the Chinese Academy of Sciences in collaboration with ESA and the Max Planck Institute for extraterrestrial Physics aimed at opening a new view of the transient high energy sky. It is a mission dedicated to time-domain astrophysics and it will discover transients and monitor variable objects in the soft X-ray band with an incredible sensitivity.

Launched in 2024, Einstein Probe will explore the sky for 3 years looking for new X-ray transients to better understand the most extreme objects in the Universe, in particular high energy flashes of cataclysmic cosmic events.

ICE-CSIC is part of the ESA Einstein Probe Science Team, and is chairing the Science Topical Panel 4 on Compact Objects, and part of the Einstein Probe Science Management Committee. Furthermore, we are part of Science Topical Panels on Fast extra-Galactic Transients and Multi-messenger events follow-up.

Recent developments

On 9 January 2024, Einstein Probe was successfully launched aboard a Long March 2C rocket from the Xichang Satellite Launch Centre in China.

In May 2024, during its commissioning phase, Einstein Probe detected a super-soft X-ray outburst from the source CXOU J005245.0-722844 in the Small Magellanic Cloud. This discovery, led by ICE-CSIC postdoctoral researcher Alessio Marino, characterised by a rapid week-long decay and spectral features indicative of nuclear burning on a white dwarf's surface, provided valuable insights into the nature of Be-white dwarf X-ray binary systems.

EINSTEIN TELESCOPE

Senior Institute members involved: C. Sopuerta, M. Mezcua, S. Husa

Department of Nuclear, Gravitational Wave and Multi-messenger Astrophysics

The Einstein Telescope (ET) is a proposed underground infrastructure to host a third-generation, gravitational-wave observatory. It builds on the success of current, second-generation laser-interferometric detectors Advanced Virgo, Advanced LIGO, and KAGRA (the LVK collaboration).

The Einstein Telescope will make it possible, for the first time, to explore the Universe through gravitational waves along its cosmic history up to the cosmological dark ages, shedding light on open questions of fundamental physics and cosmology. Following the entrance into the European Strategy Forum on Research Infrastructures, the project is now in the preparatory phase and is expected that the site and instrument configuration will be decided in 2025.

ICE-CSIC researcher Carlos F. Sopuerta is the leader of the ET-CSIC Research Unit (RU) of the Einstein Telescope Scientific Collaboration since September 2022. It is a CSIC RU that comprises five CSIC institutes including ICE-CSIC with a total number of 35 ET collaboration members. ICE-CSIC is the one that contributes more scientists to this collaboration, with a total of 20 members, covering a very wide range of topics of interest for third-generation ground-based gravitational wave detectors, like the ET.

Recent developments

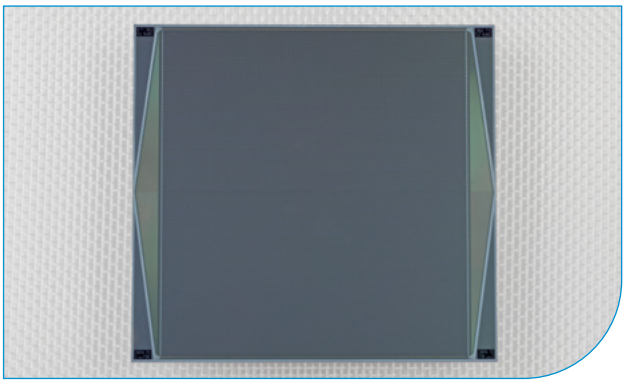
During the year 2024, the ET collaboration has been elaborating the so-called Blue Book, which contains a detailed description of the rich science case of the Einstein Telescope. Members of the CSIC ET RU have participated in different parts of the ET Blue Book.

eXTP

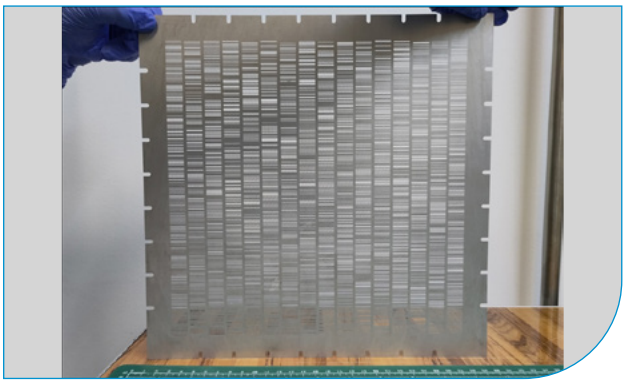
Senior Institute members involved: M. Hernanz, J.L. Gálvez, A. Patruno

Department of Star Formation, Stellar and High-energy Astrophysics

eXTP is a Chinese X-ray satellite that in its former configuration included four instruments, two led by China (IHEP/CAS) and two by Europe (INAF and ICE-CSIC), with Margarita Hernanz being the PI of the European Wide Field Monitor (WFM). However, there was a de-scoping of eXTP in February 2024 aimed to remove programmatic uncertainties, and now only the two Chinese instruments SFA (Spectral Focusing Array) and PFA (Polarimetry Focusing Array) are kept onboard.



Full size SDD detector for eXTP's WFM, designed and manufactured by INFN, INAF and FBK.
Credits: INFN and FBK.



Full size code mask with final pattern.
Credits: ICE-CSIC.

Recent developments

During 2024, ICE-CSIC continued the development of the Demonstration model of a whole WFM camera, in collaboration with the Netherlands Institute for Space Research (SRON), the National Institute for Astrophysics (INAF), and the National Institute for Nuclear Physics (INFN) institutes, and the industries SENER and Tecnalia in Spain, Thales in Italy and Neways in Netherlands. We are also still participating in the science preparation, with A. Patruno co-leading the Observatory Science Working Group.

FERMI

Senior Institute member involved: D. F. Torres

Department of Star formation, Stellar and High-energy Astrophysics

NASA's Fermi Gamma-ray Space Telescope, launched in 2008, has two gamma-ray instruments: the Large Area Telescope (LAT) and the Gamma-ray Burst Monitor (GBM). ICE-CSIC hosts a full member (D. F. Torres) in the Fermi-LAT collaboration (since 2007 before launch), to whom several students and postdocs, as well as an Affiliated Scientist (N. Rea) have been associated. The team is devoted to the study of the high-energy Galactic sky, focusing on binaries and the pulsar/pulsar-wind nebula/supernova remnant complex. We participated in the pre-launch activities, simulations and ulterior data analysis, day-to-day running of the experiment, and conducted a variety of tasks. We acted as Flare advocates & daily running checks and participated in the On-orbit calibration & development of responses and the validation of the time-difference analysis technique for radio- quiet pulsars up to helping in the preparations for several NASA Senior Science Reviews.

The highlights of the Institute's contribution to the mission include leading the collaboration work when publishing Fermi's first paper on supernova remnants observations, the first ever detection of orbital GeV variability, the first search for magnetar emission in gamma-rays, the first detection of gamma-ray emission of starburst galaxies, or the first detection of super-orbital variability, among many others. Moreover, we have also had technical involvement such as the definition of a mock population for data challenges and the development of algorithms for source class identification used in the Bright Source List and the First Fermi-LAT Catalogue, or the spectral pipeline of the Second Fermi-LAT Pulsar Catalogue.

Recent developments

ICE-CSIC continued supporting the mission and participating in its data analysis throughout 2024. PhD student O. Çoban has taken several shifts this year to track the transient gamma-ray sky and has been doing timing analysis for the enigmatic periodic source nearby the microquasar SS 433, discovered earlier at ICE-CSIC. PhD student W. Zhang focused on two studies of the diffuse emission around the magnetar Swift J1818.0-1607, and discovered a complex of molecular clouds that could explain the large-scale emission from the region. Çoban and Zhang are both doing their PhD theses with Fermi-LAT data under D.F. Torres' supervision. Torres has been also involved in the effort for understanding from a synchro-curvature theoretical perspective the global properties of the Third Catalogue of Fermi-LAT pulsars published in 2023.

HERA

Senior Institute member involved: J. M. Trigo-Rodríguez

Department of Planetary Systems and Earth Observation

Hera is an ESA mission that will visit the binary asteroid Didymos to map Didymos and Dimorphos at high resolution while it makes several technological demonstrations under low-gravity conditions. The main goal of Hera is obtaining clues on the nature and structure of both asteroids in order to use that knowledge to mitigate future encounters with hazardous asteroids.

ICE-CSIC participation in the Hera mission involves being part of the investigation team to study Didymos binary asteroid system, with emphasis in the DART-generated impact crater and the surface characteristics of Dimorphos. ICE-CSIC researcher Trigo-Rodríguez belongs to the Data Analysis, Exploitation and Interpretation working group. He is also involved in the Close Operations working group to decide the regions to be specially studied by the diverse instruments and satellites on board the Hera spacecraft. Our expertise in meteorites, and the new VIS-midIR vacuum spectrometer available at ICE-CSIC will allow us to interpret the features of the reflectance spectra received from Hera's sensors.

Recent developments

Hera was launched on 7 October 2024 from the Cape Canaveral Space Force Station in Florida, United States of America, and will reach Didymos binary system in December 2026.

LSST

Senior Institute members involved: L. Galbany, F. Castander, M. Crocce, P. Fosalba

Department of Extragalactic Astrophysics and Cosmology

The Vera C. Rubin Observatory is a cutting-edge astronomical facility in Chile, primarily tasked with conducting the Legacy Survey of Space and Time (LSST), a comprehensive synoptic survey across six bands (ugrizY). With an expected start date in late 2025, LSST will cover one-third of the southern sky every night for ten years. To maximise the scientific return from its observations, the LSST community is organised into science collaborations.

The Cosmology and Supernova research groups at ICE-CSIC are active members of the Dark Energy Science Collaboration (DESC) and the Transient and Variable Sky (TVS) Science Collaboration. The Supernova group at ICE-CSIC has been particularly active in the Type Ia supernova modeling topical team.

Recent developments

During 2024, Lluís Galbany served his second term on the DESC Collaboration Council and was elected as a temporary Deputy Publication Manager. Starting in May 2025, he will transition to the role of Publication Manager for the collaboration.

LS4

Senior Institute member involved: L. Galbany

Department of Extragalactic Astrophysics and Cosmology

The La Silla Schmidt Southern Survey (LS4) is a new time-domain survey to monitor the night sky searching for stellar explosions, stellar variables, and other transients that change brightness on timescales of minutes to years. LS4 utilises the 1m Schmidt Telescope at the La Silla Observatory (Chile) and the upgraded Quest camera, which features 32 Lawrence Berkeley National Laboratory deep-depletion CCDs and provides a total field of view of approximately 20 deg^2. Half of the focal plane observes in the i band, while the other quarters are dedicated to the g and z bands.

ICE-CSIC as an institutional member has participated in the proposal of the project and observing strategy, and has a seat in the Collaboration Council. The Supernova group at ICE-CSIC is actively involved in the supernova physics and supernova cosmology working groups.

Recent developments

The observing strategy for the five-year survey was finalised in the first few months of 2024. However, delays in the assembly and testing of the camera have shifted the survey's start date from May 2024 to March 2025. The camera was shipped in December 2024, with commissioning scheduled for January and February 2025.

NewAthena

Senior Institute members involved: N. Rea, F. Coti Zelati

Department of Nuclear, Gravitational Wave and Multi-messenger Astrophysics

The NewAthena mission, an ambitious large X-ray observatory developed by ESA, aims to revolutionise our understanding of the cosmos through multi-messenger astrophysics. Scheduled for official adoption in 2027 and a projected launch around 2036-2037, NewAthena is designed to surpass current X-ray observatories in sensitivity and capabilities.

The observatory will be equipped with two advanced instruments: a wide-field detector capable of mapping extensive sky regions to identify X-ray sources, and an integral field unit designed to capture images and spectra at each point. This combination will provide critical data on the composition and physical state of cosmic objects, enabling unprecedented precision in observing phenomena such as stellar winds and supernova explosions. The NewAthena mission is poised to open new avenues in astrophysics, offering deeper insights into the fundamental questions of modern astrophysics and the dynamic processes shaping the cosmos.

ICE-CSIC plays a significant role in the NewAthena mission. Notably, Nanda Rea is a member of the NewAthena Science Study Team, the scientific steering committee appointed by ESA to define the mission's scientific requirements and support all aspects related to its scientific return until its adoption. Additionally, approximately ten scientists from ICE-CSIC contribute to the NewAthena Topical Panels, reflecting the institute's active involvement in shaping the mission's scientific objectives.

Recent developments

In 2024, the ICE-CSIC team involved in NewAthena has been extremely busy redesigning the mission to comply with the ESA Cost Cap, meaning to re-assess all Mission Driving Scientific Objectives in view of the new instrument design. Here at ICE-CSIC we have been focusing at all Galactic science cases, simulating their feasibility with the current design and preparing for the ESA Red Book (i.e. definition study report) writing, which will take place during 2025.

ROMAN

Senior Institute member involved: L. Galbany

Department of Extragalactic Astrophysics and Cosmology

The Nancy Grace Roman Space (Roman) Telescope is a NASA 2.4m wide-field infrared space telescope, scheduled for launch into an L2 orbit by May 2027. Equipped with the Wide-Field Instrument, a 300.8-megapixel multi-band visible and near-infrared camera capable of imaging a 0.28 deg^2 field of view (100 times larger than the Hubble Space Telescope), Roman will investigate the Universe's chronology and the growth of cosmic structures, aiming to measure the effects of dark energy, test the consistency of general relativity, and explore the curvature of spacetime.

The ICE-CSIC Supernova group at ICE-CSIC is a member of the Roman Project Infrastructure Team, contributing to the development of the analysis pipeline for supernova cosmology.

Recent developments

In 2024, the team was actively involved in simulations of the Roman prism spectrograph, utilising integral field spectroscopy real data obtained with the PMAS and MUSE instruments.

SKAO

Senior Institute members involved: J.M. Girart, S. Husa, M. Mezcua, N. Rea, Á. Sánchez-Monge

Department of Extragalactic Astrophysics and Cosmology & Department of Nuclear, Gravitational Wave and Multi-messenger Astrophysics

The Square Kilometre Array Observatory (SKAO) is a next-generation radio astronomy-driven Big Data facility that will revolutionise our understanding of the Universe and the laws of fundamental physics.

The SKAO will consist of two cutting-edge arrays: 1) SKA-Low in Western Australia, comprising 131,072 low-frequency antennas, is designed to study the early Universe and the formation of the first stars and galaxies and 2) SKA-Mid in South Africa, featuring 197 mid-frequency dishes, will probe galaxy evolution, cosmic magnetism, and exoplanet systems. Composed of respectively hundreds of dishes and thousands of antennas, the SKAO's arrays will be the two most advanced radio observatories on Earth.

Together with other state-of-the-art research facilities, the SKAO will explore the unknown frontiers of science and deepen our understanding of key processes, including the formation and evolution of galaxies, fundamental physics in extreme environments and the origins of life.

ICE-CSIC is involved in several scientific working groups, such as the SKA Continuum, SKA-VLBI, SKA-Cradle of life, SKA-Our Galaxy, SKA-Cosmic Magnetism, SKA-Pulsar or SKA-Transients, and is actively contributing to writing multiple chapters of the SKAO Science Book.

Recent developments

In 2024, ICE-CSIC researchers were involved in the preparation of several chapters of the future SKAO Science Book. In addition, several are involved on the CSIC4SKA project, led by the Instituto Astrofísica Andalucía (IAA-CSIC), whose goal is to strengthen CSIC's international role on SKA.

7. Publications

7.1. Peer-reviewed Publications

In 2024, ICE-CSIC personnel participated in a total of 372 peer-reviewed publications, 109.5 more than the average in the period between 2020 and 2023.

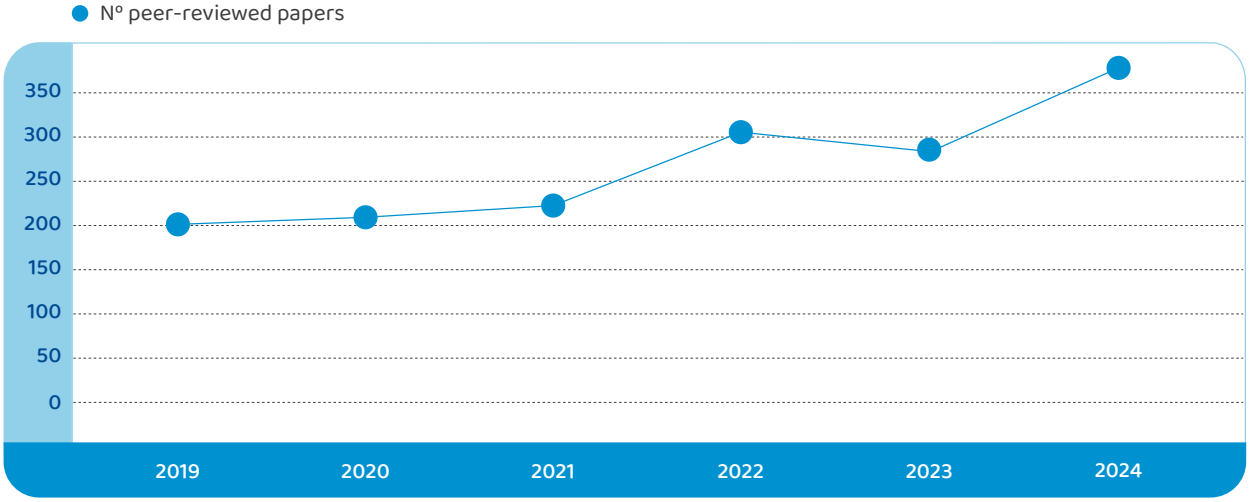
All of these publications are directly accessible from an ADS-library avalaible at the ICE-CSIC website, also listed below. The majority of the total of publications (around 93%) are in 1st quartile astrophysical journals, based on the Scientific Jounal Rankings quartiles classification of 2023.[2]

	2019	2020	2021	2022	2023	Average 2020-2023	2024
Nº peer-reviewed papers	201	221	231	313	289	263.5	372
ICE-CSIC led papers	31	38	34	74	63	52.3	100
% of papers with ICE-CSIC leadership	15.4	17.2	14.7	23.6	21.8	19.4	26.9

In 2024

- **372** peer-reviewed publications
- **93%** of publications in 1st quartile journals
- **1** publication in Nature
- **4** publications in Nature Astronomy
- **4** publications in Nature Communications
- **2,825** TOTAL CITATIONS

Nº peer-reviewed papers



[2] Full list of journals in the first quartile, according to the SJR classification: Astronomy & Astrophysics, Astroparticle Physics, AVS Quantum Science, Bulletin of the American Meteorological Society, Earth System Science Data, European Physical Journal C, Fortschritte der Physik, Geo-Spatial Information Science, IEEE Access, IEEE Geoscience and Remote Sensing Letters, IEEE Transactions on Geoscience and Remote Sensing, Measurement, Monthly Notices of the Royal Astronomical Society, Nature, Nature Astronomy, Nature Communications, Nuclear Physics B, Physical Review D, Physics of the Dark Universe, Physics Letter B, Publications of the Astronomical Society of the Pacific, Remote Sensing, Remote Sensing of Environment, Sensors, The Astronomical Journal, The Astrophysical Journal, The Astrophysical Journal Letters, The Astrophysical Journal Supplement Series, The Planetary Science Journal, Universe.

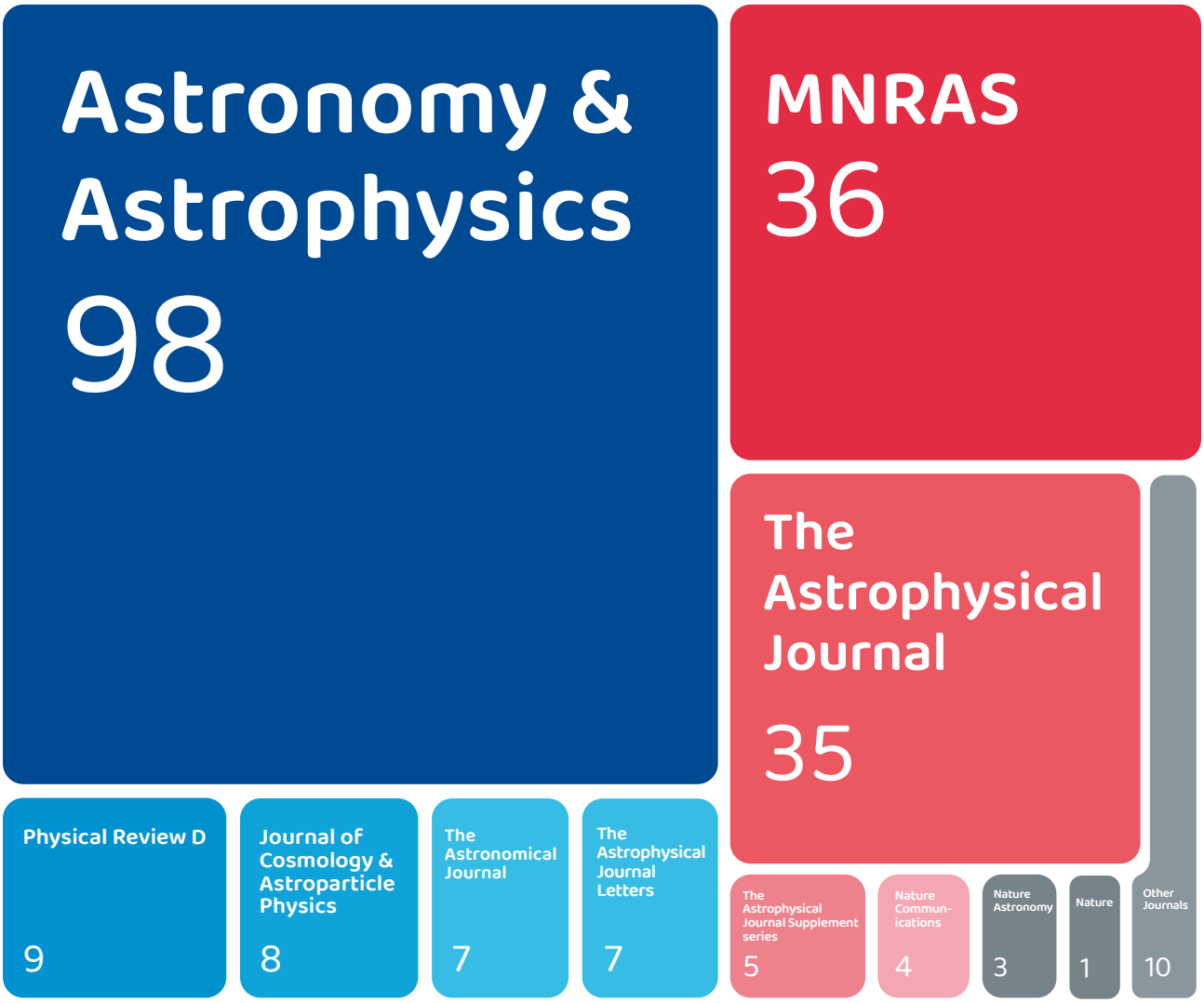
Full list of journals in the second quartile: Aerospace, Entropy, Galaxies, Icarus, Journal of Astronomical Telescopes, Instruments, and Systems, Journal of Cosmology and Astroparticle Physics, Journal of High Energy Physics, Meteoritics and Planetary Science, Symmetry.

Full list of journals in the third quartile: Astronomische Nachrichten, Revista Mexicana de Astronomia y Astrofisica.

Full list of journals in the fourth quartile: Russian Physics Journal.

Our research, in numbers

223 papers | < 15 Authors



149 papers >15 Authors

Nature

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8. Training

8.1. Postgraduate Programme in High Energy Physics, Astrophysics & Cosmology

ICE-CSIC co-organises, together with the Institut de Física d'Altes Energies (IFAE), the Postgraduate Programme of High Energy Physics, Astrophysics and Cosmology. This postgraduate programme is part of the UAB doctoral programme that has been awarded with the Spanish Mention of Quality. The master programme has a one-year duration, with 60 ECTS. Its goal is to provide students with the essential tools necessary to start a research career in any of the disciplines taught.

During the academic course 2023-2024, a total of 27 students (14 following the astrophysics itinerary coordinated by ICE-CSIC) were enrolled in the programme, from which a total of 8 students obtained their Master's degrees with theses supervised by ICE-CSIC researchers.

Defended Master's Degree theses

1. **Ramírez Pardo, A.**, *Gauge invariant and quasi-normal modes of BTZ black hole.* Supervisors: Carlos Sopuerta, Michele Lenzi. Universitat Autònoma de Barcelona, 9/7/2024.
2. **Anguera González, A.**, *Molecular composition of the IRDC G14.225-0.506.* Supervisor: Josep Miquel Girart. Universitat Autònoma de Barcelona, 9/7/2024.
3. **Hernández Oliu, R.**, *Enhancing Salt Production Pond Monitoring: Integrating Weather and In-Situ Data through Machine Learning.* Supervisor: Estel Cardellach. Universitat Autònoma de Barcelona, 9/7/2024.
4. **Sanfeliu Rupérez, R.**, *Estimating SHOES cepheids local metallicity to improve the measurement of H0.* Supervisor: Lluis Galbany. Universitat Autònoma de Barcelona, 10/7/2024.
5. **Souki, A.**, *Cosmological parameter estimation in the preparation of the Euclid survey.* Supervisors: Martin Crocce, Anna Porredón. Universitat Autònoma de Barcelona, 25/7/2024
6. **Auguets Boixadé, Q.**, *Spectral analysis and molecular identification of the massive star-forming region W75N.* Supervisor: Álvaro Sánchez-Monge. Universitat Autònoma de Barcelona, 3/9/2024.
7. **Rodríguez Salazar, M.**, *Searching for building blocks of life in the outer Galaxy.* Supervisor: Álvaro Sánchez-Monge. Universitat Autònoma de Barcelona, 3/9/2024.
8. **Pavel,I.**, *The spectral shape of the X-ray binary populations in nearby galaxies.* Supervisor: Konstantinos Kovlakas. Universitat Autònoma de Barcelona, 4/9/2024.

8.2. PhD Programme

ICE-CSIC hosts PhD candidates carrying out a programme of independent research supervised by ICE-CSIC researchers. As of 31 December 2024, there were a total of 45 PhD students (12 women and 33 men) at the Institute, 17 from Catalonia, 9 from the rest of Spain, 3 from Europe and 16 from the rest of the world. In 2024, six of them started their PhD and five PhD students defended their PhD theses.

Defended PhD theses

1. **Peña Asensio, E.**, *A Comprehensive Study of the Fireball Flux Over the Earth.* Supervisors: Josep M. Trigo-Rodríguez, Albert Rimola Gibert. Universitat Autònoma de Barcelona. 10/1/2024.

   Abstract: This thesis investigates meteoric phenomena in the context of the Spanish Fireball and Meteorite Network. It introduces 3D-FireTOC, a tool for meteor detection and analysis that uses computer vision and machine learning. The study of fireballs and superbolides from ground-based stations and satellites suggests

that one-quarter of the large impactors originate from the known near-Earth population. The research also explores interstellar candidates, finding six in the Center for Near-Earth Objects database, exhibiting non-low strength compositions. One of these events, along with a hyperbolic meteor recorded in Finland, is compatible with the passage of Scholz's binary star system through the Oort Cloud. These findings challenge conventional Solar System formation models, as impactors showed high strength, unlike expected cometary compositions.

Eloy Peña-Asensio during his PhD defense.
Credits: ICE-CSIC.

2. **Ronchi, M.,** *Population synthesis of Galactic pulsars with machine learning.* Supervisors: Nanda Rea, Vanessa Graber. Universitat Autònoma de Barcelona. 8/2/2024.

Abstract: This thesis combines population synthesis studies of galactic isolated neutron stars with deep learning techniques to understand neutron-star birth properties and evolution. We developed a flexible population-synthesis framework to model the dynamics and magneto-rotational evolution of neutron stars and their emission in radio. We explored the use of deep neural networks to infer the properties of neutron stars at birth and use a simulation-based inference framework to constrain physical models from the observed radio pulsar population. This thesis also investigates the mysterious nature of recently discovered periodic radio sources with very long periods, considering neutron stars interacting with supernova fallback disks and exploring the possibility of magnetic white dwarfs emitting coherently through magnetic dipolar losses.

Michele Ronchi during his PhD defense.
Credits: ICE-CSIC.

3. **Ibrahim, A.**, *Search for transient events and pulsars in multi-frequency data. Supervisors:* Nanda Rea, Francesco Coti Zelati. Universitat Autònoma de Barcelona. 3/10/2024.

Abstract: This thesis focuses on the study of neutron stars, particularly magnetars, using multi-wavelength observations in X-ray and radio bands. It includes an analysis of the first detected outbursts of Swift J1818.0-1607 and the 2022 reactivation of the galactic magnetar SGR J1935+2154. These analyses reveal key insights into the emission properties, torque variability, and magnetospheric processes during magnetar outburst events. The thesis also explores radio observations of the magnetic white dwarf ZTF J1901+1458 to search for dipolar emission from the source. We also introduce the eBANDERAS pipeline, a tool we are developing for detecting and analysing X-ray transient events across various missions. This work contributes to our understanding of neutron star outbursts as well as establishes new detection tools for detecting transient sources in the current and future X-ray surveys.

Abubakr Ibrahim (middle) with Francesco Coti Zelati (left) and Nanda Rea (right).
Credits: ICE-CSIC.

4. **Navarro, D.**, *A study of photometric redshifts and intrinsic alignments with PAUS and Euclid.* Supervisors: Martin Crocce, Enrique Gaztañaga. Universitat Autònoma de Barcelona, 15/10/2024.

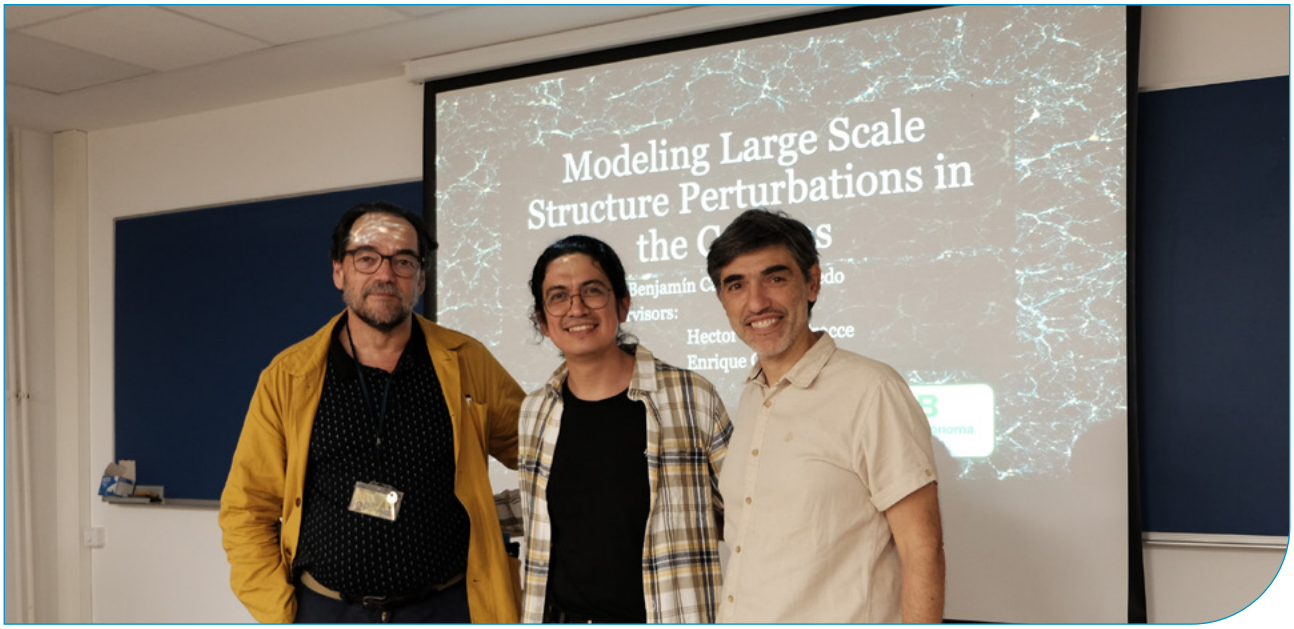
David Navarro (middle) with Enrique Gaztañaga (left) and Martín Crocce (right).
Credits: ICE-CSIC.

Abstract: The field of cosmology is undergoing an era of unprecedented new observational data, with galaxy surveys collecting information from billions of galaxies. This will enable the scientific community to perform precise measurements of the large-scale structure of the Universe, enhancing our understanding about the cosmological model that best describes it. This thesis focuses on photometric redshift (photo-z) estimation

and the study of intrinsic alignments (IA) with the Physics of the Accelerating Universe Survey (PAUS) and Euclid. First, we employ PAUS to estimate the distances to galaxies, via photo-z, for ~1.8 million objects in an area of ~50 deg^2 and down to iAB < 23. We employ a template-fitting code to estimate photo-z and implement a novel zero-point calibration, which does not require spectroscopic redshifts. We define an innovative weighting scheme, where the photo-z estimates from PAUS and broad-band (BB) data are combined. This allows us to achieve photo-z accuracies one order of magnitude better than BB estimates for bright objects, while reducing the number of outliers and the bias. We analyse the photo-z accuracy as a function of the galaxy colour, finding similar performances for red and blue objects. Additionally, we provide calibrated probability density distributions of the photo-z for each object. Next, using the previously computed photo-z, we measure the galaxy clustering (GC) and the IA of galaxies in the PAUS fields, for 400,000 objects in the redshift range $0.1 < z < 1.0$. We analyse the dependence on colour, redshift and luminosity and constrain the GC and IA parameters for each scenario. The results show significant detection of IA for red galaxies, with an increase in the signal at high redshifts and luminosities. In contrast, blue galaxies show null or weak alignments. In general, our results are consistent with previous literature, extending the IA amplitude-luminosity relation towards fainter objects. Finally, we implement the Tidal Alignment and Tidal Torquing IA model in Euclid's likelihood pipeline. Then, we perform forecasts on how IA affects cosmological parameter inference, demonstrating that the mismodelling of the IA effect might lead to biases in the cosmological parameters. Therefore, we highlight the need of adding flexible IA models for accurate cosmological inference in upcoming galaxy surveys.

5. **Camacho, B.,** *Modeling large scale structure perturbations in the cosmos.* Supervisors: Martin Crocce, Enrique Gaztañaga. Universitat Autònoma de Barcelona, 16/10/2024.

Abstract: Discovering the nature and composition of matter and energy in the Universe remains one of cosmology's most significant challenges. The distribution of these components, particularly dark energy and dark matter—collectively known as the dark sector, which accounts for about 95% of the total energy budget—governs the Universe's evolution. This thesis investigates cosmic perturbations with two key objectives: first, to examine potential anomalies in the standard cosmological model by testing its foundational assumptions, and second, to develop statistical tools to constrain the cosmological parameters of the Lambda Cold Dark Matter model. The analysis is divided into two regimes. In the first, we explore perturbations in the linear regime, characterizing early-Universe fluctuations and testing a core assumption of the current model—the cosmological principle. In the second regime, we examine perturbations in the mildly non-linear domain, focusing on extracting information from galaxy clustering through the galaxy power spectrum in redshift space. For both investigations, we developed new theoretical and computational tools. In the first, we derived formulas to calculate the fractal dimension of the Cosmic Microwave Background temperature fluctuation map. In the second, we designed an emulator for the power spectrum multipoles, allowing for faster yet accurate computations.



Benjamín Camacho (middle) with Enrique Gaztañaga (left) and Martín Crocce (right).
Credits: ICE-CSIC.

Ongoing PhD theses

1. **Alburai, A.**, *Characterizing underluminous type Ia supernovae at low and high redshift.* Supervisor: Lluís Galbany. Universitat Autònoma de Barcelona.

2. **Alemany, M.**, *Cartografiado extragaláctico para estudiar la energía oscura, preparación para Euclid.* Supervisors: Pablo Fosalba, Isaac Tutusaus. Universitat Autònoma de Barcelona.

3. **Anguera, A.**, *Constraining the evolutionary stages of protostellar cores through their chemical and dust properties.* Supervisors: Alvaro Sanchez-Monge, Gemma Busquet Rico. Universitat de Barcelona.

4. **Baghkhani, Z.**, *Simulating the Universe to exploit large cosmological surveys.* Supervisor: Francisco Javier Castander. Universitat Autònoma de Barcelona.

5. **Blanco, J.**, *Machine learning approaches to high resolution spectroscopy for exoplanets.* Supervisors: Guillem Anglada-Escudé, Manuel Perger. Universitat de Barcelona

6. **Blázquez, C.**, *Physical modelling of the activity of the star AU Mic. to reveal planetary signals.* Supervisor: Ignasi Ribas. Universitat Autònoma de Barcelona.

7. **Camacho, G.**, *Cosmology with galaxy surveys.* Supervisor: Alex Alarcón. Universitat Autònoma de Barcelona.

8. **Canalda, X.**, *Root Zone Soil Moisture (RZSM) measurements using signals of opportunity at P and L-band.* Supervisors: Serni Ribó, Weiqiang Li. Universitat Politècnica de Catalunya.

9. **Coloma, J.M.**, *Cosmología con cartografiados de galaxias.* Supervisor: Martin Crocce. Universitat Autònoma de Barcelona.

10. **Çoban, Ö.F.**, *Spectral and Temporal Analysis of Compact Objects with Fermi-LAT.* Supervisors: Diego F. Torres, Jian Li, Daniela Hadasch. Universitat Autònoma de Barcelona.

11. **D'Onofrio, S.**, *Modified gravity and early-universe cosmology.* Supervisor: Sergei Odintsov. Universitat Autònoma de Barcelona.

12. **Díaz, E.**, *Characterization of the young stellar population in Orion A.* Supervisors: Gemma Busquet, Josep Miquel Girart. Universitat de Barcelona.

13. **Díaz, P.**, *Mixing Processes in Low and Intermediate-Mass Stars on the Age of Asteroseismology.* Supervisor: Aldo Serenelli. Universitat Autònoma de Barcelona.

14. **Du, H.**, *Innovative processing techniques for operational ocean surface wind measurements from spaceborne GNSS-Reflectometry.* Supervisors: Weiqiang LI, Estel Cardellach. Universitat de Barcelona.

15. **Elias, A.**, *Magnetic imprints and evolution in exoplanets.* Supervisors: Daniele Viganò, Fabio del Sordo. Universitat Autònoma de Barcelona.

16. **Eróstegui, A.**, *A search for dual AGN in galactic mergers across mass scales.* Supervisor: Mar Mezcua. Universitat Autònoma de Barcelona.

17. **Fernández, P.**, *Testing the Black Hole no-hair conjecture with Extreme-Mass-Ratio Inspirals.* Supervisor: Carlos F. Sopuerta. Universitat Autònoma de Barcelona.

18. **Gambardella, G.**, *Galaxy Clustering in redshift surveys: cosmology from Euclid and DESI.* Supervisor: Martin Crocce. Universitat Autònoma de Barcelona.

19. **González, G.**, *Exploitation of GNSS Reflectometry for Innovative Cryosphere Products.* Supervisor: Estel Cardellach. Universitat Politècnica de Catalunya (UPC).

20. **González, M.**, *Observational studies of stripped-envelope supernovae.* Supervisors: Claudia Gutierrez, Lluís Galbany. Universitat Autònoma de Barcelona.

21. **Grèbol, P.**, *Physicochemical properties of meteorites and their ablation phases on Earth's atmosphere.* Supervisors: Josep Maria Trigo-Rodríguez, Jordi Ibáñez. Universitat Autònoma de Barcelona.

22. **Gualani, V.**, *High stability optical resonator for gravitational astronomy: optical clock and nano-kelvin precision thermometry.* Supervisor: Miquel Nofrarias. Universitat Autònoma de Barcelona.

23. **Hernández, J. L.**, *Transport properties in neutron stars and neutron star mergers.* Supervisors: Cristina Manuel, Laura Tolos. Universitat de Barcelona.

24. **Huang, B.**, *Magnetized clustered star formation in Orion.* Supervisor: Josep Miquel Girart. Universitat Autònoma de Barcelona.

25. **Íñiguez, D.**, *Spectral and light-curve modelling of the synchro-curvature emission from pulsars.* Supervisors: Diego F. Torres, Daniele Viganò. Universitat Autònoma de Barcelona.

26. **Jiménez, C.**, *SNIa environments.* Supervisor: Lluís Galbany. Universitat Autònoma de Barcelona.

27. **Kaur, S.**, *Radio Emission from exoplanetary systems.* Supervisors: Daniele Viganò, Josep Miquel Girart. Universitat Autònoma de Barcelona.

28. **Martín Vílchez, I.**, *Development of Data Analysis and Parameter Estimation Algorithms and Waveform models for the LISA mission.* Supervisor: Carlos Sopuerta. Universitat Autònoma de Barcelona.

29. **Pardo, C.**, *Exploring neutron-star astrophysics with machine learning.* Supervisors: Vanessa Graber, Nanda Rea. Universitat Autònoma de Barcelona.

30. **Paz, A.**, *Applications of Polarimetric Radio Occultations for Numerical Weather Prediction modelling.* Supervisors: Ramon Padullés, Estel Cardellach. Universitat de Barcelona.

31. **Peng, J.**, *Innovative bistatic reflectometry of land surfaces using signals of opportunity.* Supervisor: Estel Cardellach. Universitat Politècnica de Catalunya.

32. **Phan, K.**, *SNIa NIR.* Supervisor: Lluís Galbany. Universitat Autònoma de Barcelona.

33. **Porqueras, O.**, *Mitigating stellar activity to characterise exoplanet atmospheres.* Supervisors: Juan Carlos Morales, Manuel Perger. Universitat Autònoma de Barcelona.

34. **Pirvu, R.**, *Stellar populations in Local Group galaxies and beyond: observational constraints, population synthesis modeling and the resulting dust production.* Supervisors: Franciska Kemper, Aldo Serenelli. Universitat Autònoma de Barcelona.

35. **Rodríguez, C.**, *Study of hidden features in Accreting Neutron Stars.* Supervisors: Alessandro Patruno, Diego F. Torres. Universitat Autònoma de Barcelona.

36. **Rodríguez, V.**, *AGN outflows in dwarf galaxies.* Supervisor: Mar Mezcua. Universitat Autònoma de Barcelona.

37. **Serrano, D.**, *Magnetic induced forces in LISA.* Supervisor: Miquel Nofrarias. Universitat Autònoma de Barcelona.

38. **Soriano, C.**, *Cooling of magnetic exoplanets.* Supervisors: Daniele Viganò, Rosalba Perna. Universitat Autònoma de Barcelona.

39. **Torki, M.**, *Stellar and galactic physics with large-scale surveys.* Supervisor: Aldo Serenelli. Universitat Autònoma de Barcelona.

40. **Untzaga, J.**, *A search for wandering intermediate-mass black holes in the Milky Way.* Supervisors: Mar Mezcua, Silvia Bonoli. Universitat Autònoma de Barcelona.

41. **Wan, Y.**, *Advanced GNSS reflectometry instrumental concepts for swarms of nanosatellites.* Supervisors: Estel Cardellach, Serni Ribó. Universitat Politècnica de Catalunya.

42. **Viglione, C.N.**, *Mining future galaxy surveys with cosmological weak lensing magnification.* Supervisor: Pablo Fosalba. Universitat Autònoma de Barcelona.

43. **Zhang, W.**, *High energy emission from nebulae at different stages of evolution.* Supervisors: Diego F. Torres, Jonatan Martín. Universitat Autònoma de Barcelona.

44. **Zhou, X.**, *Research on Satellite-Ground Synergistic GNSS-R for Monitoring the Dynamic Parameters of the Sea Surface During Typhoon Storm Surges.* Supervisors: Qin Zhang, Estel Cardellach. Universitat Autònoma de Barcelona.

45. **Zuleta, A.**, *Investigating the evolution of astrophysical dust: constraints from observations at millimeter wavelengths.* Supervisors: Anaëlle Maury, Luca Cacciapuoti. Universitat Autònoma de Barcelona.

External theses

(students not residing in ICE-CSIC, but supervised by ICE-CSIC members)

1. **Alibekova, Z.**, *Gravitating spinor fields in modified gravity theories.* Supervisor: Sergei D. Odintsov. Al Farabi University, Almaty, Kazakhstan.

2. **Berkutbaeva, R.**, *Mass gap for a gravitating monopole interacting with a nonlinear spinor field.* Supervisor: Sergei D. Odintsov. Al Farabi University, Almaty, Kazakhstan.

3. **Comadran Casas, M.**, *Effective field theories for hot and/or dense relativistic plasmas.* Supervisor: Cristina Manuel. Universitat de Barcelona.

4. **Cross, D.**, *Sigma8 at high and low z.* Supervisors: Carlos Sanchez, Lluís Galbany. Universitat Autònoma de Barcelona.

5. **Gascón, C.**, *Multiwavelength data-analysis techniques for high-contrast imaging of Terrestrial exoplanets.* Supervisors: Guillem Anglada, Ignasi Ribas. Center for Astrophysics, Cambridge, MA.

6. **González-Díaz, R.**, *Diffuse gas.* Supervisor: Lluís Galbany. Universitat Autònoma de Barcelona.

7. **Kochankovski, H.**, *Strongly coupled matter in neutron star mergers.* Supervisor: Laura Tolós. Universitat de Barcelona.

8. **Montesinos Llácer, V.**, *Exotic states. Study at finite density and temperature.* Supervisor: Laura Tolós. IFIC-Universitat de Valencia.

9. **Rodriguez Martínez, H.**, *Wildfire risk assessment with AI and remote sensing data.* Supervisor: Estel Cardellach. Universitat Politècnica de Catalunya.

8.3. Summer School

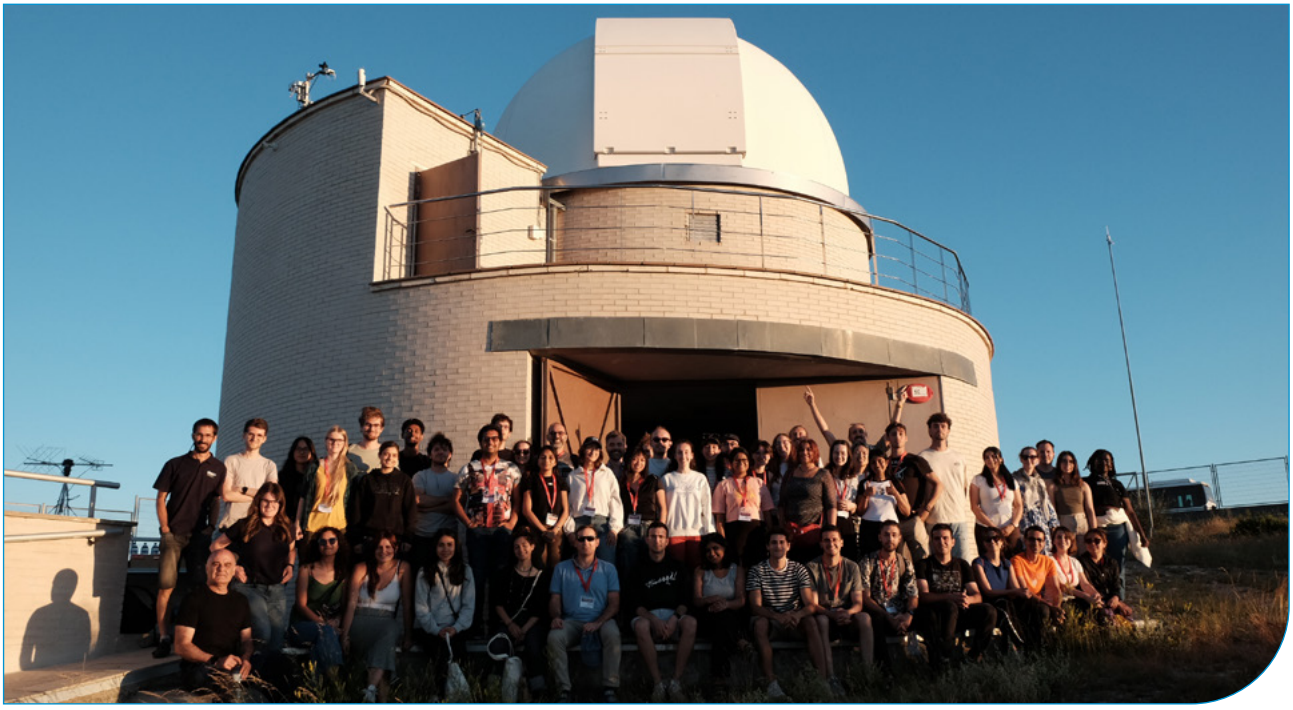
The 7th ICE-CSIC Summer School, devoted to the topic "Multiwavelength Approach to Exoplanetary Systems", took place on 2-11 July 2024, and welcomed 42 early-career researchers from 17 different countries.

The two-week long school was organised by Noemí Cortés, Jordi Blanco Pozo, Albert Elias López, Nuno Gomes, Simranpreet Kaur, Juan Carlos Morales, Manuel Perger, Fabio del Sordo, Clàudia Soriano, and Daniele Viganò.

The school programme included both theoretical lectures and hands-on sessions led by ICE-CSIC host lecturers and ten external experts from all over the world.

During the first week, lectures and hands-on sessions introduced students to the most successful techniques to discover exoplanets. The lectures also covered the challenges posed by stellar magnetic activity to detect exoplanets, a hot topic in the field, including a review of artificial intelligence techniques to overcome this problem. Another interesting topic covered was the study of exoplanet atmospheres using low and high resolution spectroscopy. In addition, the participants had the opportunity to re-analyse observations from the JWST Early Data Release. During the second week, the sessions were focused on the elusive exoplanetary magnetism, in particular related to the magnetic star-planet interaction and their radio, optical and X-ray counterparts. The effects of flaring activity and high-energy emission from the stars on their planets were also discussed.

Furthermore, a visit to the Montsec Observatory was organised. The students were introduced to the different observational facilities installed there such as the Joan Oró Telescope and the Fabra-ROA Montsec telescope. Besides, they also had the opportunity to monitor the transit of an exoplanet. The photometry was later reduced during a final hands-on session.



Group picture of the ICE-CSIC Summer School 2024 participants during the visit to Montsec Observatory.
Credits: ICE-CSIC.

9. Conferences and Seminars

9.1. Pizza Seminars

1. **Hernanz, M.**, *Explosions of white dwarfs as novae and their role in the origin of Lithium-7 and cosmic rays*, 12/1/2024
2. **Calejero, A.**, *The Magnet alliance: bringing astronomy to the classroom to fight scholar segregation*, 19/1/2024
3. **Camisassa, M.**, *White dwarf stars in the Gaia era*, 26/1/2024
4. **Pardo, C.**, *Isolated pulsar population synthesis with simulation-based inference*, 2/2/2024
5. **Karimbu, A.**, *Meta-materials and Meta-surfaces: Exploring Applications and Research Opportunities in Radio Astronomy*, 9/2/2024
6. **Sopuerta, C.F.**, *Exploring the Universe with LISA*, 16/2/2024
7. **Untzaga, J.**, *A link to the past: Searching for wandering intermediate-mass black holes in the Milky Way*, 23/2/2024
8. **Guzmán, F.**, *Optical technologies for astrophysics, Earth and planetary sciences*, 1/3/2024
9. **Soriano, C., Lenzi, M.**, *ICE-CSIC María de Maeztu Best paper Awards 2024*, 8/3/2024
10. **Eggemeier, A.**, *Cosmological constraints from two- and three-point galaxy clustering*, 15/3/2024
11. **Illiano, G.**, *Snooping around millisecond pulsars: can accretion- and rotation-powered states co-exist?*, 22/3/2024
12. **Rubio, M.**, *Strong gravity beyond Einstein's gravity: from "the quantum" to "the cosmo"*, 05/04/2024
13. **Elizalde, E.**, *Who was the first to discover that our Universe expands and that it had an origin?*, 12/4/2024
14. **Trigo-Rodríguez, J.M.**, *The amazing geology and structure of Dimorphos: challenge or opportunity for asteroid deflection?*, 19/4/2024
15. **Foucart, F.**, *From chirps to gold: colliding neutron stars as a laboratory for extreme physics*, 26/4/2024
16. **Maggiore, M.**, *Fundamental Physics and Cosmology with the Einstein Telescope*, 3/5/2024
17. **Peterson, E.**, *Improving the Hubble Diagram on Both Axes*, 10/5/2024
18. **Marino, A., Dehman, C., Kovlakas, K., Rea, N.**, *Constraints on the dense matter equation of state from young and cold isolated neutron stars*, 16/5/2024
19. **González, L.**, *Thermal analysis & Hypatia*, 24/5/2024
20. **Meyer, D.**, *Supernova remnants of massive stars*, 31/5/2024
21. **Gaztañaga, E.**, *CMB anomalies and parity asymmetry*, 7/6/2024
22. **Márquez, I.**, *Outflows in low-power active galaxies, LINERs*, 14/6/2024
23. **Dharmawardena, T.**, *The 3D structure of the Milky Way using fast & scalable Gaussian Processes*, 21/6/2024
24. **Dax, M.**, *Simulation-based inference enables real-time analysis of gravitational waves*, 27/6/2024
25. **Paiella, L.**, *Seeds to success: growing heavy black holes in dense star clusters*, 11/10/2024
26. **Ramakrishnan, S.**, *Techniques for making realistic astronomical survey mocks*, 18/10/2024
27. **Rodríguez-Kamenetzky, A.**, *The Radio Anatomy of Protostellar Jets*, 25/10/2024
28. **Venturini, J.**, *The radius valley of exoplanets for single and binary stars*, 08/11/2024
29. **Gieles, M.**, *Formation of globular clusters with extremely massive stars*, 15/11/2024
30. **Gkini, A.**, *Eruptive mass loss prior to superluminous supernova*, 22/11/2024
31. **Rosselli, D.**, *Growth-Rate measurement using peculiar velocities from LSST type Ia supernovae*, 29/11/2024
32. **Senior PhD students at ICE-CSIC**, *Bullet #PizzaSeminar - Senior PhD edition*, 13/12/2024

9.2. ICE-CSIC Colloquia and Invited Seminars

1. **Ng, C.** *Cradle of Life science with the SKA, ICE-CSIC Colloquia,* 7/3/2024
2. **Márquez, I.**, *Astronomy, a woman's thing?, ICE-CSIC Colloquia,* 14/6/2024
3. **Lechuga, L.**, *Revolutionizing Human Health Diagnostics with Point-of-care Nanophotonic Biosensors, ICE-CSIC Colloquia,* 12/12/2024
4. **Tancredi, G.**, The Fireball *Network BOCOSUR, ICE-CSIC Invited Seminar,* 11/1/2024
5. **Kyritsis, E.**, *The first all-sky survey of star-forming galaxies with eROSITA,* ICE-CSIC Invited Seminar, 26/2/2024
6. **Wiseman, J.J.**, *The Hubble Space Telescope: A New Era of Discovery,* ICE-CSIC Invited Seminar, 6/5/2024
7. **Kim, W.**, *Cycles of interstellar molecules between local and global environments,* ICE-CSIC Invited Seminar, 30/7/2024
8. **Rajwade, K.**, *A zoo of radio transients from SKA-precursors,* ICE-CSIC Invited Seminar, 2/10/2024
9. **Israel, G. L.**, *BALROGs: Beyond the Accretion Limits and the Rise Of pulsating Gems,* ICE-CSIC Invited Seminar, 16/10/2024
10. **Jiménez, D.**, *Parametric resonances in domain walls and cosmic strings,* ICE-CSIC Invited Seminar, 7/11/2024
11. **Alameri, N.**, *SAASST: A Hub for Space Science, Innovation, and Public Engagement,* ICE-CSIC Invited Seminar, 28/11/2024
12. **Sciotti, D.**, *Modelling uncertainties for the Euclid mission,* ICE-CSIC Invited Seminar, 11/12/2024

9.3. Workshops and meetings organised at ICE-CSIC

1. **LISA Formulation Management Team meeting**
   17-19/4/2024
2. **Euclid Spain Meeting 2024**
   18-19/4/2024
3. **3rd Barcelona Initiative for Gravitation and Cosmology (BIG&C)**
   17/5/2024
4. **Pencil Code User Meeting**
   23-27/10/2024
5. **Cross-Collserola PhD Meeting in Astrophysics, Cosmology and Particles 2024**
   4/10/2024
6. **LISA Spain Meeting**
   15-16/10/2024
7. **4th BIG Meeting: Barcelona Initiative for Gravitation**
   29/11/2024
8. **Horizon Europe MSCA Glitter "Remote sensors and small-satellites systems for Earth Observation" School**
   25-29/11/2024

Group picture Cross-Collserola PhD Meeting in Astrophysics, Cosmology and Particles 2024.
Credits: ICE-CSIC.

9.4. External conferences, seminars and congresses

Including the following selection

1. **Mezcua, M.**, *Universidad de Valencia,* Valencia, Spain, Invited talk, 18/1/2024
2. **Tolos, L.**, *Hyperon interactions: the state-of-the-art and applications, "Physics opportunities with proton beams at SIS100",* Invited talk, 6/2/2024
3. **Campos, N.**, *Scheduling software to plan the operations of space missions and astronomical instruments,* Terrassa, 28/2/2024
4. **Castander, F. J.**, *Simulations to speed up galaxy properties computations, Simulation Based Inference for Galaxy Evolution,* Bristol, United Kingdom, Contributed talk, 9-12/4/2024
5. **Castander, F. J.**, *The PAU Camera and Survey, Start Golen Years: go strong after KiDS,* Leiden, Contributed talk, 8-10/4/2024
6. **Rea, N.**, *Jornades de Relativitat de Terrassa,* 27/4/2024
7. **Mezcua, M.**, *Massive Black Holes in the First Billion Years,* Kinsale, Ireland, Invited talk, 30/4/2024
8. **Odintsov, S.**, *Cosmology and Astrophysics in the Gravitational Wave Astronomy Era,* Thessaloniki, Greece, 6-10/5/2024
9. **Mezcua, M.**, *Barcelona Initiative for Gravitation and Cosmology,* Cerdanyola del Vallès, Spain, Invited talk, 17/5/2024
10. **Rea, N., Hernanz, M.**, *XMN - Newton workshop 2024,* ESAC, Madrid, 5-7/6/2024
11. **Hernanz, M.**, *The WFM (Wide Field Monitor) onboard eXTP (enhanced X-ray Timing and Polarimetry mission). Technological Status in Spain,* AstroHEP-PPCC24, Zaragoza, Spain, Invited talk, 5-7/6/2024
12. **Hernanz, M.**, *Gamma-rays from novae related to radioactive decay and their detectability, 244th Meeting of the American Astronomical Society,* Madison (Wisconsin), USA, Invited talk, 12/6/2024
13. **Hernanz, M.**, *Feroci, M., et al. including, Álvarez, D., Carmona, A., Gálvez, J., Patruno, A., The Wide Field Monitor (WFM) of the China-Europe eXTP (enhanced X-ray Timing and Polarimetry) mission,* SPIE ASTRONOMICAL TELESCOPES + INSTRUMENTATION, Yokohama, Japan, Contributed talk, 16-22/6/2024
14. **Froning, C.S., Roming, P., Ray, P., et al. including, Hernanz, M., Patruno, A.**, *STROBE-X: capturing the universe in motion, SPIE ASTRONOMICAL TELESCOPES + INSTRUMENTATION,* Yokohama, Japan, Contributed talk, 16-22/6/2024
15. **Ceraudo, F., Evangelista, Y., Hernanz, M., in ´t Zand, J., Kuiper, L., Patruno, A.**, *Development of the end-to-end simulator of the WFM camera, SPIE ASTRONOMICAL TELESCOPES + INSTRUMENTATION,* Yokohama, Japan, 16-22/6/2024
16. **Serenelli, A., Karimbu, A., Ribó, S., Nofrarias, M., Cirera, J.M.**, *Micro Space.s Forum: Driving Synergies between IMB-CNM-CSIC and ICE-CSIC,* Bellaterra, Spain, 25/6/2024
17. **Sopuerta, C.**, SORS: Computational challenges of the LISA mission, Barcelona Supercomputing Centre, Barcelona, Spain, 28/6/2024
18. **Galbany, L.**, European Astronomical Society 2024, Padova, Italy, 1-5/7/2024
19. **Kovlakas, K.**, 2024 Summer School for AstroStatistics in Crete, Greece, 8-12/7/2024
20. **Tolos, L.**, 10th International Conference on Quarks and Nuclear Physics(QNP2024), Barcelona, Spain, 8-12/7/2024
21. **Hernanz, M., Patruno, A., Gálvez, J., Álvarez, D., Carmona, A.**, *eXTP and STROBE-X in Spain*, SEA 2024, Granada, Spain, Contributed review, 15-19/7/2024
22. **Rea, N., Hernanz, M.**, SEA 2024: Spanish participation in X-ray observatories, Granada, Spain, 16-17/7/2024
23. **Galbany, L., Rea, N.**, SEA 2024: Astrophysical transients and time domain astronomy, 18-19/7/2024
24. **Fosalba, P.**, *The Universe in our hands: the rise of the space sciences in Spain*, UCM Course, El Escorial, Madrid, 22-26/7/2024
25. **Mezcua, M.**, *Cosmic Origins: The First Billion Years, Kavli Institute for Theoretical Physics*, Santa Barbara (California), USA, Invited talk, 8/8/2024
26. **Odintsov, S.D.**, *Computer science and gravitation*, Baku, Azerbaijan, 19-23/8/2024

27. **Manuel, C.**, *The high temperature QCD static potential,* QuantFunc, Valencia, Invited talk, 2-6/9/2024

28. **Galbany, L., Montes, M., Montoro, A.**, Congress LSST@ Europe6, La Palma, Canary Islands, Spain, 16-20/9/2024

29. **Tolos, L.**, FAIRNESS 2024, Seget Donji, Croatia, 23-28/9/2024

30. **Montes, M.**, *Explorando las sombras del Universo,* XXX Conference on Astronomy & Cosmology Carlos Sánchez Magro, Valladolid, Spain, 4/10/2024

31. **Manuel, C.**, *Damping of density oscillations from bulk viscosity in quark matter, Compact Stars in the QCD Phase Diagram,* Kyoto, Japan, Contributed talk, 7-11/10/2024

32. **Odintsov, S.D.**, *Introduction to modified gravity, Kyoto University,* Kyoto, Japan, 19/11/2024

33. **Ribas, I.**, *Present and future of exoplanet research,* ICMAB, Barcelona, Spain, 25/11/2024

9.5. PhD Seminars

1. **Jiménez, C.**, *Environmental properties of Type Ia supernovae.* **Paz, A.**, *Co-location and validation of PRO data aboard PAZ using NEXRAD weather radars,* 16/1/2024

2. **Camacho, G.**, *The CMB lensing imprint of cosmic voids.* **D'Onofrio, S.**, *Generalized entropic cosmology,* 19/2/2024

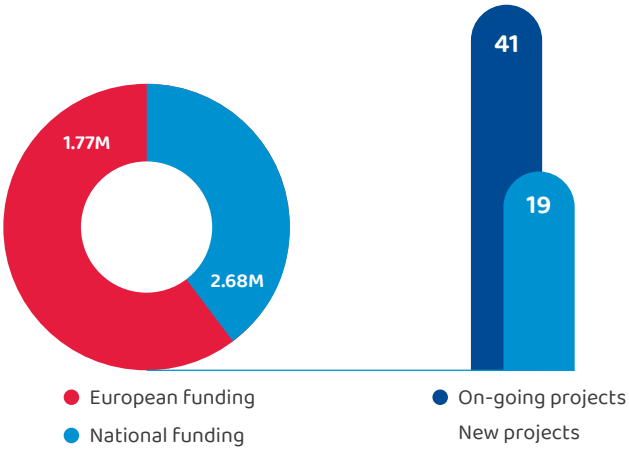
3. **Hernández, L.**, *Damping of density oscillations from bulk viscosity in quark matter.* **Rodríguez, V.**, *AGN outflows in dwarf galaxies using MaNGA integral-field spectroscopy,* 19/3/2024

4. **Ibrahim, A.**, *On magnetar outbursts: The 2022 reactivation of the magnetar SGRJ1935+2154.* **Fariña, L.**, *Design of an advance Gamma-ray trigger or HERD,* 21/5/2024

5. **Mezcua, M., Padullés, R., Vinyoles, N., Blay, E.**, *Round table: Future perspectives after the PhD,* 7/6/2024

10. Projects

In 2024, ICE-CSIC received competitive funding for 19 new scientific projects for a total of around 4.45 million euros, distributed in 1.77 million euros from national funding and 2.68 million euros from European funding. Another 41 projects were on-going during 2024, for a total of 60 active projects.



10.1. New projects

1. **Project code:** CNS2023-145240
   Title: Exploración de las condiciones prístinas para transformar el polvo interestelar en planetesimales
   IP: Maury, A.J.
   Funding Source: AEI-MICIN

2. **Project code:** PID2023-149918NB-I00
   Title: Propiedades, evolución, vientos y remanentes de estrellas de masa baja e intermedias
   IP: Serenelli, A.
   Funding Source: AEI-MICIN

3. **Project code:** PID2023-146675NB-I00
   Title: Formación Estelar en la Galaxia: Un Enfoque Estadístico
   IPs: Girart, J.M., Sánchez-Monge, A.
   Funding Source: AEI-MICIN

4. **Project code:** PID2023-150491NB-I00
   Title: Aprendizaje de Máquina para mitigar actividad estelar en la investigación de Exoplanetas
   IP: Anglada-Escudé, G.
   Funding Source: AEI-MICIN

5. **Project code:** PID2023-153229NA-I00
   Title: Paleta Cósmica: Un modelo físico para entender los colores y la estructura cosmológica en el Universo
   IP: Alarcón, A.
   Funding Source: AEI-MICIN

6. **Project code:** PID2023-151307NB-I00
   Title: Facilitando la siguiente generación de cosmología con supernovas
   IP: Galbany, Ll.
   Funding Source: AEI-MICIN

7. **Project code:** 202450E110
   Title: Exploración de las condiciones prístinas para transformar el polvo interestelar en planetesimales
   IP: Maury, A. J.
   Funding Source: CSIC

8. **Project code:** 20245PRC05
   Title: Machine learning methods for analysis of X-ray timing data
   IP: Serenelli, A.
   Funding Source: AEI-MICIN

9. **Project code:** PCI2024-153513
   Title: Spanish contribution to LISA: Diagnostics systems development and scientific exploitation-IEEC
   IP: Nofrarias, M.
   Funding Source: IEEC

10. **Project code:** PDC2023-145848-I00
    Title: Sensor miniaturizado MEMS de campo magnético de bajo ruido y con prestaciones de espacio
    IP: Nofrarias, M.
    Funding Source: IEEC

11. **Project code:** COOPB23040
    Title: Modelos y Observaciones de Supernovas en el proyecto Precision Observations of Infant Supernova Explosions (POISE)
    IP: Galbany, Ll.
    Funding Source: CSIC

12. **Project code:** 101120117
    Title: GNSS-R satellite Earth observation
    IP: Cardellach, E.
    Funding Source: HORIZON-MSCA-2022-DN-01

13. **Project code:** 101126626
    Title: Artificial intelligence in sustainable development goals
    IP: Serenelli, A.
    Funding Source: HORIZON-MSCA-2022-COFUND-01

14. **Project code:** 101149286
    Title: Mitigating stellar magnetic activity contamination in Transmission spectroscopy
    IP: Ribas, I.
    Funding Source: HORIZON-MSCA-2023-PF-01

15. **Project code:** 101098309
    Title: Exploring the pristine conditions for transforming interstellar dust into planetesimals
    IP: Maury, A. J.
    Funding Source: ERC-2022-ADG

16. **Project code:** 101140786
Title: Physical modelling of stellar activity effects to discover and measure exoearths
IP: Anglada-Escudé, G.
Funding Source: ERC-2023-ADG

17. **Project code:** ESA CN 4000142425/23/NL/AS/ov SSTL-Subcontract-MS000483
Title: HydroSwarm
IP: Cardellach, E.
Funding Source: ESA

18. **Project code:** ESA CN 4000144239/24/NL/LF/ar (subcontract Open Cosmos)
Title: Spanish Component of the Atlantic Constellation (Phase 1)
IP: Cardellach, E.
Funding Source: European Space Agency

19. **Project code:** FUNDS24073
Title: Distintivo FUNDS STG/COG/ADV/SYG-01 2024 en el Instituto de Ciencias del Espacio
IP: Serenelli, A.
Funding Source: FUNDS2024

10.2. Ongoing Projects

1. **Project code:** CEX2020-001058-M
Title: Unidades de Excelencia María de Maeztu
IP: Torres, D.F.
Funding Source: AEI-MICIN

2. **Project code:** PID2020-115253GA-I00
Title: Acorralando la "tensión de Hubble" estudiando errores sistemáticos y reconstruyendo el universo local con supernovas
IP: Galbany, L.
Funding Source: AEI-MICIN

3. **Project code:** PID2020-117710GB-I00
Title: Primeras etapas de la formación estelar en entornos magnetizados: estudios de polarización
IP: Girart, J. M.
Funding Source: AEI-MICIN

4. **Project code:** PID2020-120375GB-I00
Title: Aprendizaje automático con datos y modelos para la detección de exoplanetas cercanos parecidos a la Tierra (DMLEXO)
IP: Anglada-Escudé, G.
Funding Source: AEI-MICIN

5. **Project code:** 20215AT007
Title: Spaceborne Coherent GNSS Reflectometry: Model, Processing and Applications
IP: Li, W.
Funding Source: CSIC

6. **Project code:** 20215AT016
Title: Cornering the Hubble tension using supernovae in the local universe
IP: Galbany, L.
Funding Source: CSIC

7. **Project code:** PID2021-126436OB-C22
Title: GENESIS, GNSS environmental and societal missions - parte CSIC
IPs: Cardellach, E., Ribó, S.
Funding Source: AEI-MICIN

8. **Project code:** TED2021-129812B-I00
Title: Medición de humedad del suelo a profundidad utilizando drones
IPs: Ribó, S., Cardellach, E.
Funding Source: AEI-MICIN

9. **Project code:** PID2021-124243NB-C22
Title: Agujeros negros en crecimiento: desde las primeras semillas hasta los núcleos activos de galaxia
IP: Mezcua, M.
Funding Source: AEI-MICIN

10. **Project code:** PID2021-124581OB-I00
Title: Investigación fundamental e innovación tecnológica para avanzar la ciencia de púlsares
IPs: Torres, D. F., Patruno A.
Funding Source: AEI-MICIN

11. **Project code:** PID2021-128062NB-I00
Title: Propiedades físico-químicas de asteroides y cometas a partir del estudio en el laboratorio de meteoritos y muestras retornadas
IP: Trigo-Rodríguez, J.M.
Funding Source: AEI-MICIN

12. **Project code:** PID2021-128989NB-I00
Title: Cosmología con cartografiados de galaxias
IP: Crocce, M.
Funding Source: AEI-MICIN

13. **Project code:** 202250E071
Title: The nano-physics of interstellar silicates
IP: Kemper, F.
Funding Source: CSIC

14. **Project code:** 202250E103
Title: Cosmología con Cartografiados Extragalácticos
IP: Castander, F. J.
Funding Source: CSIC

15. **Project code:** 2021 SGR 00426
Title: MAP: Enfoque multimensajero de la física de astropartículas
IP: Torres, D. F.
Funding Source: Generalitat de Catalunya

16. **Project code:** 817661
Title: Magnetar Census: the impact of highly magnetic neutron stars in the explosive and transient Universe
IP: Rea, N.
Funding Source: H2020-ERC

17. **Project code:** 948582
Title: Imprints of Magnetic fields in Exoplanets
IP: Viganò, D.
Funding Source: H2020-ERC

18. **Project code:** 101008324
Title: ChETEC, Chemical Elements as Tracers of the Evolution of the Cosmos - Infrastructures for Nuclear Astrophysics
IP: Serenelli, A.
Funding Source: H2020-INFRAIA

19. **Project code:** 101030103
Title: REVERSI, REVealing the Effects of Star-planet Interactions
IP: Del Sordo, F.
Funding Source: H2020-MSCA

20. **Project code:** NewSpaceCat-IEEC-Innotech-PLBandProcessing4EO
Title: Algorithms and INSTITUTE OF SPACE SCIENCES81 modelling for reflectometry techniques on P and L bands (SoOP-P+L)
IP: Cardellach, E.
Funding Source: IEEC

21. **Project code:** ROM-SAF-CDOP4
Title: EUMETSAT Radio Occultation Meteorology Satellite Application Facility: 4th Continuous Development and Operations Phase
IP: Cardellach, E.
Funding Source: EUMETSAT

22. **Project code:** ESA CN 4000135686/21/NL/AD SSTL-SubContract-MS000430
Title: HydroGNSS Phase B to E2 I
IP: Cardellach, E.
Funding Source: ESA

23. **Project code:** SGR01270
Title: Extragalactic Extreme and Transient Universe
IPs: Galbany, L., Mezcua, M.
Funding Source: AGAUR

24. **Project code:** Dragon 5 proposal Id. 58070
Title: Calibration And Validation Of The First Chinese GNSS-R Mission—Bufeng-1 A/B
IP: Li, W.
Funding Source: ESA

25. **Project code:** PID2019-104397GB-I00
Title: MUESQA, Modelos de evolución del Universo y sus singularidades: Aspectos clásicos y cuánticos
IPs: Elizalde, E., Odintsov, S. D.
Funding Source: AEI-MICIN

26. **Project code:** RYC2017-21810
Title: Exploring the Extremes of Physics with Compact Stars
IP: Patruno, A.
Funding Source: CSIC

27. **Project code:** OTR08994
Title: Becas de postdoctorado Junior Leader 2022
IP: Sánchez, C.
Funding Source: Fundación La Caixa

28. **Project code:** 4000135481/21/NL/AR
Title: Optical Fiber Micro-kelvin Temperature Sensor Network for Sensitive Optical Payloads
IP: Nofrarias, M.
Funding Source: ESA

29. **Project code:** 4000128647/19/NL/BW
Title: LISA Phase-A Instrument Study for a Gravitational Wave Observatory
IP: Nofrarias, M.
Funding Source: ESA

30. **Project code:** 4000127051/19/NL/BW
Title: Enhanced temperature measurement for LISA
IP: Nofrarias, M.
Funding Source: ESA

31. **Project code:** RFP/3- 17761/22/NL/IB/gg
Title: LISA Payload Data and Diagnostics Subsystem
IP: Nofrarias, M.
Funding Source: CDTI/ESA (PRODEX)

32. **Project code:** OTR11043
Title: Becas de postdoctorado Junior Leader 2023
IP: Alarcón, A.
Funding Source: Fundación La Caixa

33. **Project code:** 101086388
Title: LACEGAL, Latin American Chinese European Galaxy Formation Network
IP: Posalba, P.
Funding Source: HORIZON-MSCA-2021-SE-01

34. **Project code:** PID2022-139427NB-I00
Title: Teorías efectivas de las interacciones nucleares fuertes en condiciones extremas
IPs: Manuel, C., Tolós, L.
Funding Source: AEI-MICIN

35. **Project code:** LINKA20409
Title: Type Ia supernova in the near-infrared to map the cosmography of Laniakea
IP: Galbany, Ll.
Funding Source: CSIC

36. **Project code:** CNS2022-136050
Title: Machine Learning for Extreme precision Doppler spectroscopy
IP: Anglada-Escudé, G.
Funding Source: AEI-MICIN

37. **Project code:** 202350E189
Title: Potenciando la Unidad de Ingeniería Avanzada en el ICE (Boosting the Advanced Engineering Unit at ICE)
IP: Serenelli, A.
Funding Source: CSIC

38. **Project code:** CA26273
Title: Tecnologías Avanzadas Para la Exploración del Universo
IP: Serenelli, A.
Funding Source: AEI-MICIN & Generalitat de Catalunya

39. **Project code:** PCI2023-146001-2
Title: Dark Energy Cosmological Surveys, Exploiting Euclid-IEEC
IP: Castander, F. J.
Funding Source: AEI-MICIN

40. **Project code:** PID2022-141079NB-C31
Title: COSMO_EUCLID22 – Dark Energy Cosmological Surveys, exploiting Euclid and other surveys (PID2022)
IP: Castander, F. J.
Funding Source: AEI-MICIN

41. **Project code:** PID2022-138896NB-C52
Title: ARRAKIHS: Primera fase de la próxima misión espacial de clase-F de la Agencia Espacial Europea
IP: Fosalba, P.
Funding Source: AEI-MICIN

11. Awards and Distinctions

11.1. Awards

Enrique Gaztañaga awarded with the Freedom of the City of London

ICE-CSIC and IEEC researcher Enrique Gaztañaga was awarded the Freedom of the City of London in a ceremony dating back to medieval England. He was recognised for his significant contributions to the Measuring the Monument working group, which aims to recreate the measurements taken in the 1670s using the London Monument to prove that the Earth orbits the Sun.

Enrique Gaztañaga (left) receiving an award from the Lord Mayor Professor Michael Mainelli (right).
Credits: University of Portsmouth.

Guillem Anglada-Escudé, awarded the Serra d'Or Crítica Award for the book *A city on Mars*

ICE-CSIC and IEEC researcher Guillem Anglada-Escudé was one of the winners of the 58th edition of the Crítica Awards, held at Espai Endesa in Barcelona on 3 April 2024. He was recognised for his book A City on Mars, available in Spanish and Catalan, which explores the characteristics of the Red Planet and envisions what life there could be like. The book details Nüwa, a futuristic city designed by the International Sustainable Offworld Network (SONet) to sustain human life on Mars. The Nüwa project was among the ten finalists in The Mars Society's international Mars City State Design competition in 2020.

Guillem Anglada-Escudé (second from left) together with co-authors of the book A city on Mars at the award ceremony.
Credits: Vinyet Peñarroya.

Clàudia Soriano receives the special Aerospace mention at the 2024 DonaTIC Awards

The ICE-CSIC PhD student Clàudia Soriano received a special mention in the Aerospace category at the tenth edition of the DonaTIC Awards.

Clàudia Soriano received the DonaTIC 2024 award, special mention Aerospace, on 10 October 2024 at an event held in the Paloma room in Barcelona.
Credits: Generalitat de Catalunya.

11.2. Distinctions

1. **Clara Dehman** was recognised by the Spanish Astronomical Society (SEA) with a Special mention at the SEA PhD Awards 2024 for her PhD thesis "Unveiling the Physics of Neutron Stars: A 3D expedition into Magneto-Thermal evolution in Isolated Neutron Stars with 'MATINS'", more information.

2. **The International Astronomical Union** named an asteroid after Ignasi Ribas, more information.

12. Communication and Outreach

The ICE-CSIC Communication and Outreach Office coordinates and organises different communication and outreach initiatives to expand the visibility of the Institute's activities among the general public, the national and international community of astronomers, engineers, students and teachers, families, journalists and policymakers.

12.1. Communication

ICE-CSIC published 47 pieces in 2024 (20 scientific news, 19 institutional news and 8 outreach news) [see Section 13 for more details]. Of those, we coordinated 21 press releases in collaboration with the CSIC, CSIC delegation in Catalonia and IEEC Communication Offices to reach out to press at regional and national level. These led to a total of 1,262 appearances in media outlets.

Regarding our online presence, the ICE-CSIC Communication and Outreach Office manages the ICE-CSIC website and runs the ICE-CSIC social media channels, including X, YouTube, LinkedIn and Instagram. The Office was also in charge of the ICE-CSIC newsletter, which was published four times in 2024.

Overall, ICE-CSIC central communication activities had a total reach of around 173,164 people (see breakdown in infographic), with an extended reach of around 4,393 million people considering media coverage[4]. Among our most relevant projects, the ICE-CSIC Communication and Outreach Office also coordinated specific activities to reach wider audiences. For instance, on the occasion of the International Day of Women and Girls in Science on February 11th, we launched a social media campaign called #HowItAllStarted featuring the women working at the institute in different fields (research, engineering and administration) explaining what they do, their background and what took them to pursue a career in science. The campaign released videos once a week until 8 March 2024 to commemorate the International Women's Day but continued throughout the year with a total of 9 videos published. The campaign was aimed to be extended until March 2025. In addition, the Communication and Outreach Office participated twice in the weekly collaboration between CSIC and the science programme A Hombros de Gigantes from *Radio Nacional de España*. We collaborated with a short section on the release of a new cosmic distance catalogue by PAUS survey on September 22nd and another one on the discovery of the longest period radio transient event detected to date on November 30th.

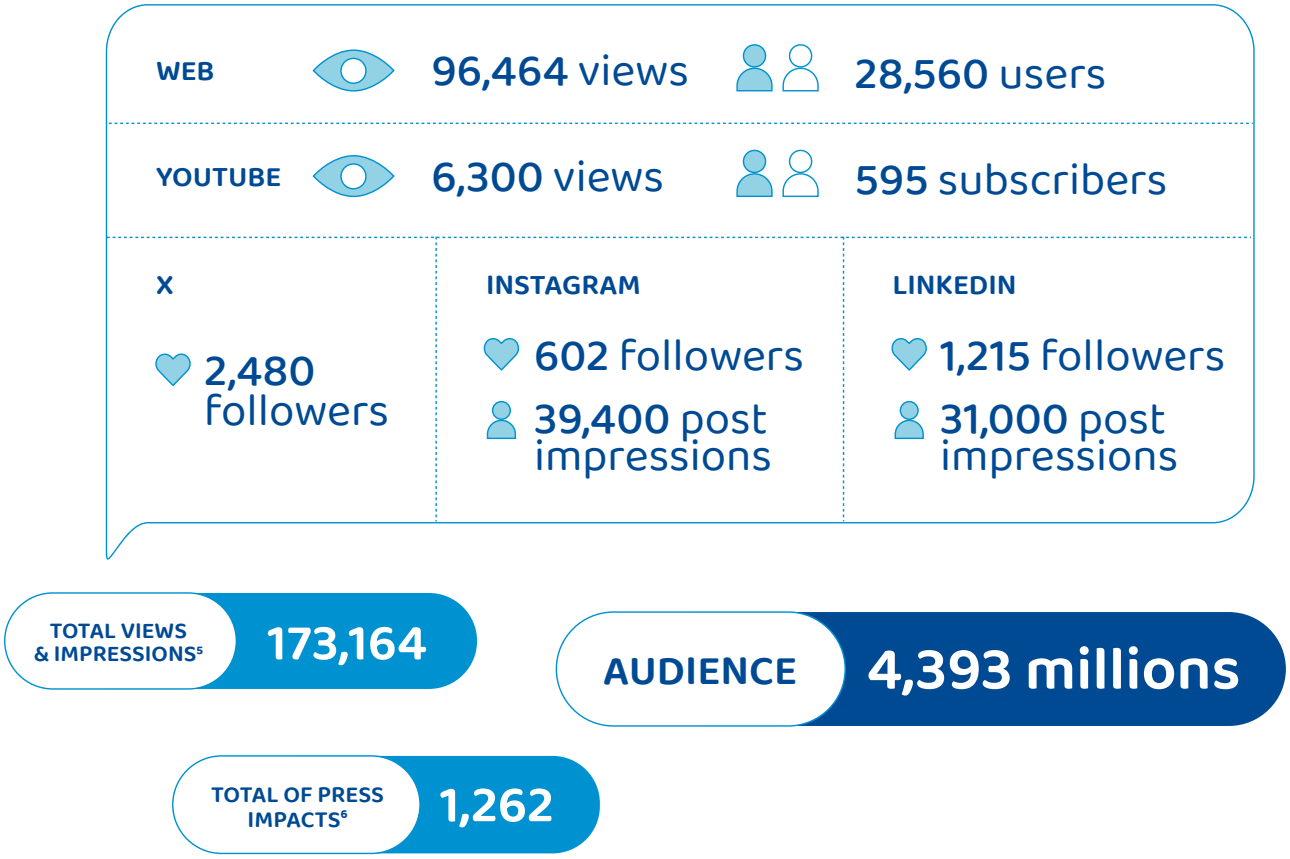
During the year the ICE-CSIC Communication and Outreach Office also coordinated press inquiries for ICE-CSIC researchers and received visits from 3Cat reporters to record interviews.

As part of the preparations for ICE-CSIC's 25th anniversary, we developed a commemorative logo for the Institute to be used during 2025 as well as a special visual design for the commemorative conference held in February 2025. At the end of 2024, the Communication and Outreach Office also focused on the production of an institutional video to be released in early 2025.

Finally, the Communication and Outreach Office acted as the Spanish Communication contact point for the Euclid Consortium and supported the coordinated communication efforts of Spanish institutions.

[4] The data related to press impacts and audience only accounts for media in Spain, as indicated by the information compiled through the press clipping service provided by CSIC.

ICE-CSIC Communication Channels Impacts



12.2. Outreach

In 2024, we continued our commitment to bring astronomy closer to society through our public engagement actions.

Magnet alliance

ICE-CSIC continued its participation in the Magnet Alliance with the school Gabriel Castellà i Raich in Igualada, Barcelona. The project, led by the Bofill Foundation, aims to provide the school with added pedagogical and educational value to fight school segregation. During this year, our activities involved the participation of 29 ICE-CSIC members (9 women and 20 men) who brought astronomy topics to the classrooms and organised visits to perform hands-on activities with the students. To further support the teachers, 2 teacher trainings were held during the year.

A special aspect of the Magnet activities this year involved supporting the school in disseminating the actions of the project to families and the general public in Igualada. Among them: an Open Day event for families in February that included the online participation of former Spanish astronaut Pedro Duque, who shared some memories about being in space and interacted with students answering their questions; a science-cafe event in March including a series of three talks from ICE-CSIC researchers Alessio Marino, María Kopsacheili and Juan Carlos Morales combined with quizzes; and

[5] This figure is the result of the addition of the ICE-CSIC website views, YouTube views, Instagram post impressions and LinkedIn post impressions. X post impressions were not included because from 2024 onwards it is not possible to retrieve those statistics unless you have a premium account.

[6] The number of press impacts and audience only accounts for media in Spain since is the information available through press clipping service provided by CSIC.

Group pictureof the 5th Primary Education class from Escola Gabriel Castellà to ICE-CSIC in the framework of the Magnet Alliance.
Credits: ICE-CSIC.

the participation at the European Researchers' Night activity at the school, where students and families enjoyed solar observations with researchers María Kopsacheili, Maider González and Rebeca Pirvu, as well as a talk by researchers Álvaro Sánchez-Monge and Manuel Perger.

Finally, we were glad to receive two visits from the students and teachers to our headquarters. In May, to close the 2023-2024 academic year, we welcomed the fifth grade class where they presented what they had learnt during the year and visited our laboratories. Then, in September, we opened the 2024-2025 academic year with a co-creation session with all teachers from the school. In this session, moderated by the Bofill Foundation, ICE-CSIC members and teachers set-up the goals for the final year of our magnet collaboration.

A course on didactic tools for CSIC personnel

As part of the CSIC Scientific Education Group, the ICE-CSIC Communication and Outreach Office took part in designing and planning the course "Didactic tools to bring science closer to the classrooms" offered by CSIC training office to the personnel of all CSIC centres in Spain. The course took place in April 2024 and was addressed to scientific and technical personnel involved in outreach and educational activities. This first edition of the course involved the participation of 50 students. It was an online course taught by teachers from different educational levels, experts in didactics and professionals involved in the educational field. With a practical approach, attendees had to work in groups to design an educational activity addressed to students from a specific educational level.

CSIC Ciencia en el barrio

Another CSIC educational initiative we were involved in 2024 was Ciencia en el Barrio. This project brings science closer to students and people in socio-economic challenged neighborhoods in Barcelona by organising activities in high-schools and civic centres. We started participating during the second half of 2024 with the organisation of an educational workshop about the dark Universe in a civic centre in the Nou Barris neighbourhood (Barcelona) and a talk from an ICE-CSIC researcher at a high-school.

Amanar

Inclusion actions were also a central part of our activities. Within the Amanar project, that supports the Sahrawi refugee community through astronomy, two ICE-CSIC members participated in a one-week visit to the Sahrawi camps near Tindouf (Algeria) in the framework of the FiSahara International Film Festival. There, the Amanar project presented the Virtual Reality experience Desert Stars, reaching out to hundreds of Sahrawis and international participants of the festival. Furthermore, Amanar visited two schools organising astronomy hands-on activities and telescope observations, which reached over 300 students and 15 teachers. Besides the visit to the camps, we continued organising the Amanar Summer programme in Barcelona for the Sahrawi children spending their summer in Spain with host families in the framework of the 'Holidays in Peace' programme. The activity - held at the Vil·la Urània civic centre in Barcelona - comprised an afternoon of hands-on activities and telescope observations for around 25 Sahrawi children and their host families.

Group picture during the activities of the Amanar project at schools at the Sahrawi camps near Tindouf, Algeria.
Credits: GalileoMobile.

International Day of Women and Girls in Science

In addition to the #HowItAllStarted campaign described above, on the occasion of the International Day of Women and Girls in Science February 11th, several ICE-CSIC female researchers joined the #100tífiques initiative, by giving face-to-face and online talks to Primary and High school students in Catalonia about the work of a scientist and their experience as women in research. Our researchers also joined other local and national initiatives such as 'Chat with an Astronomer' organised by the Spanish Astronomical Society.

Astronomy activities for visually-impaired people

To extend our inclusive actions, we performed a pilot activity for visually impaired people using astronomy 3D tactile materials. Organised together with the Vil·la Urània civic centre and the Instituto Municipal de Discapacidad de Barcelona, 12 visually impaired people of all ages and their accompanying persons were able to learn about planets, stars and galaxies.

Local and national outreach festivities

To reach out to the general public we organised educational workshops and telescope observations in major science outreach festivities in the region such as Festa de la Ciència 2025 in Barcelona (June) and the European Researchers' Night activities at the UAB Campus in Bellaterra (September).

ICE-CSIC booth at the Festa de la Ciència Barcelona 2024.
Credits: ICE-CSIC.

ICE-CSIC members Simone D'Onofrio (left) and Michele Lenzi (right) discussing about space-time and gravity at ICE-CSIC booth at the European Researchers' Night activities at UAB Campus in September 2024.
Credits: ICE-CSIC.

Within the framework of CSIC's Science and Technology Week in November, we organised a full-week of events, including night-sky observations at the UAB campus; 2 science-cafe events at a civic centre in Barcelona; a guided tour to our facilities; and the aforementioned activities for visually impaired people.

Alessio Marino giving a talk during a science-cafe activity at the Civic Centre La Pau in the framework of ICE-CSIC activities for the CSIC Science and Technology Week 2024.
Credits: ICE-CSIC.

Education fairs

To promote the Institute's activities and especially the opportunities for students, we were present at three student fairs. In March, we attended for the first time Saló de l'Ensenyament, the largest fair for high-school students in Catalonia, where we interacted with over 100 high-school students through an educational workshop on the dark Universe. In April, we participated with a stand on the XVIII Fira de Ciències i Enginyeries UB, interacting with over 300 astronomy/science students. Finally, at the end of April, we returned to the MEMEnginy congress, which is organised by UAB's Engineer Faculty - with a stand where around 250 Engineering students interested in pursuing a career in engineering were able to network with our AEU members.

12.2.1. Outreach initiatives by ICE-CSIC researchers

ICE-CSIC researchers are quite active developing their own outreach projects and collaborating with researchers from other institutions to reach a greater audience. In addition, they were involved in 34 outreach activities and talks organised by external institutions.

Find below some of the main outreach initiatives by ICE-CSIC researchers during 2024.

The Spanish Meteor Network (SPMN)

The Spanish Fireball and Meteorite Recovery Network (SPMN) is a citizen science project coordinated by Josep M. Trigo-Rodríguez. He is a Research Scientist and leader of ICE-CSIC's Asteroids, Comets and Meteorites Group, whose members in 2024, Eloy Peña-Asensio and Pau Grèbol-Tomàs, were also involved in its scientific exploitation.

Bolide SPMN211224Z registered from Estepa, Sevilla, Spain.
Credits: SPMN / Antonio J. Robles.

This professional-amateur (ProAm) project monitors Spain and neighbouring countries from 60 stations operated by 70 amateur astronomers and 10 researchers involved to some extent in the network tasks. Every station contributes with video data almost every night, recording the most luminous meteors, mostly at night but sometimes also in broad daylight. In consequence, the continuous operation of the stations allows this video network to record thousands of fireballs every year. Some of these events are a direct consequence of the continuous impacts among asteroids, producing sub-metric rocks that reach the Earth as sporadic fireballs. Other fireballs are associated with specific meteoroid streams, being released from asteroids or comets.

During 2024, the network had excellent weather conditions and obtained a new record in collecting scientific data. As a result, the SPMN collected data for 4,235 bright meteors and fireballs, corresponding to 120 Gb of data. We monitored all the main meteor showers, particularly having favourable displays of Quadrantids, Virginids, Lyrids, Eta Aquarids, Delta Aquarids, Perseids, Orionid, Taurids, and Geminids. Particularly spectacular were August and December displays of Perseids and Geminids meteor showers, respectively. Again, we beated the previous 2023 record, almost duplicating the amount of meteors saved in our database.

In addition, in the framework of the Project Stardust, the expert in urban micrometeorites Jon Larsen collaborated with Josep M. Trigo-Rodríguez searching for micrometeorites at the rooftops of Institut Baix Montseny in Sant Celoni with 25 students. The analysis of the dust collected on that journey is still not complete, but it was a great experience for everyone involved.

Territorio Gravedad

Territorio Gravedad is an outreach series produced by CSIC and Lipssync Medialab, which premiered on TV and platforms in 2023. This hybrid between a documentary and fiction outlines a visit to the cosmos using gravity as a common thread. The first four chapters are free on RTVE Play, available until 14 February 2026. The first 8 chapters were available on Filmin in 2023. In November 2024, the four last episodes were released on *Filmin* and *Vimeo On Demand*. The documentary features several members of the ICE-CSIC Gravitational Astronomy research group, which currently leads the Spanish contribution to the ESA's space mission LISA, such as Carlos Sopuerta, Miquel Nofrarias, Víctor Martín and Sascha Husa.

Blogs

Dark Cosmos, a blog by the ICE-CSIC Extragalactic Astrophysics and Cosmology Group.

Blog by Josep M. Trigo-Rodríguez at *The Conversation España*.

Researcher Josep M. Trigo-Rodríguez is the Scientific Director and promoter of DivulCat, a scientific outreach project (a blog of blogs) maintained by scientists from Catalan-speaking territories. Several ICE-CSIC researchers collaborate with their own blog:

- Obrint els ulls..., a blog by Emilio Elizalde on *Divulcat*.
- La deu de l'únic vers, a blog by Lluís Galbany on *Divulcat*.
- Ciències planetàries i meteorits, a blog by Josep M. Trigo-Rodríguez on *Divulcat*.

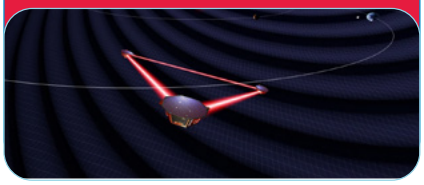
13. News

09/01/2024

The Einstein Probe will explore the sky looking for extreme X-ray transients

25/01/2024

LISA, the first gravitational-wave observatory in space gets go-ahead

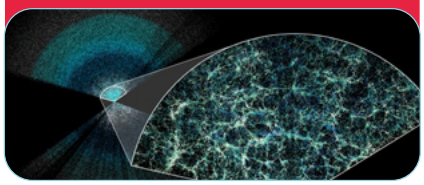


28/01/2024

La Caixa Foundation awards research grant to a Postdoctoral Fellow at ICE-CSIC

04/04/2024

First results from DESI make the most precise measurement of our expanding Universe



16/04/2024

The SPOTLESS project receives an ERC Advanced Grant

18/04/2024

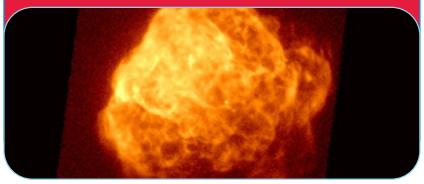
ICE-CSIC participates in the European ALLIES program to move towards a sustainable future

23/04/2024

LISA Consortium Constitutional Council gets together in Barcelona

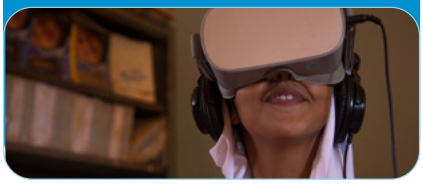
27/04/2024

Einstein Probe opens its wide eyes to the X-ray sky



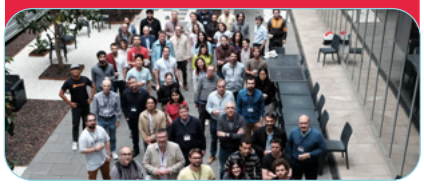
29/04/2024

GalileoMobile Amanar returns to the Tindouf refugee camps



03/05/2024

ICE-CSIC holds the Euclid Spain Meeting 2024



06/05/2024

Supermassive black holes detected for the first time in low-mass galaxies at intermediate stages of the Universe

23/05/2024

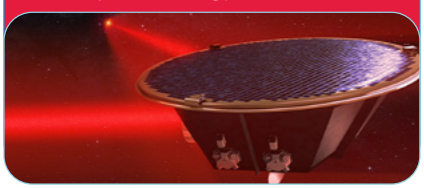
ESA's Euclid celebrates first science with sparkling cosmic views

03/06/2024

The ARRAKIHS mission passes in record time a critical phase in the development of its 'brain' to study dark matter

05/06/2024

The ILIADA project, selected in the call to test technology on board the next satellite mission of the NewSpace Strategy



10/06/2024

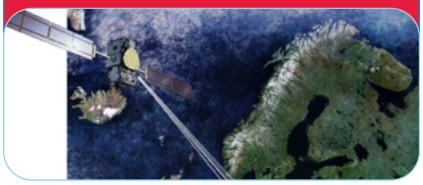
Aldo Serenelli, new director of the Institute of Space Sciences (ICE-CSIC)

11/07/2024

The project DeepSpacePULSE obtains an ERC Proof of Concept grant from the European Research Council

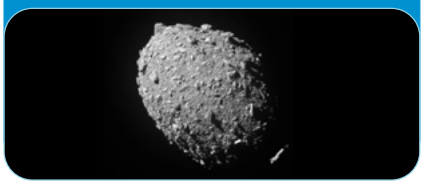
25/07/2024

ICE-CSIC participates in the GLITTER project to train the next generation of Earth observers



30/07/2024

NASA's DART mission captures the Didymos binary asteroid system in high resolution

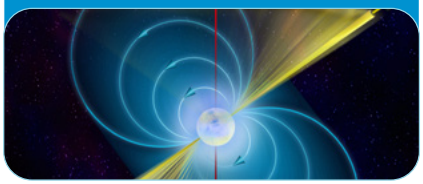


06/08/2024

Astronomers find that the May 18th giant superbolide possibly originated in a Jupiter-family comet

14/08/2024

A team of astronomers offers new insights into the evolution of pulsarst



09/09/2024

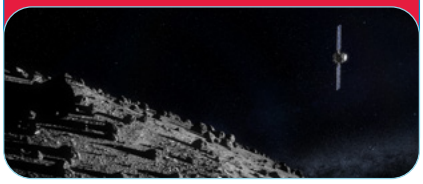
ICE-CSIC participates in the recognition ceremony for the Severo Ochoa and María de Maeztu accreditations

13/09/2024

ICE-CSIC and Gabriel Castellà i Raich school begin the fourth year of the Magnet alliance

07/10/2024

ICE-CSIC participates in ESA's Hera planetary defence mission



25/10/2024

ICE-CSIC holds the first LISA Spain meeting after the adoption of the mission

04/11/2024

Astronomers discover the fastest-feeding black hole in the early Universe

20/11/2024

New DESI Results Weigh In On Gravity

26/11/2024

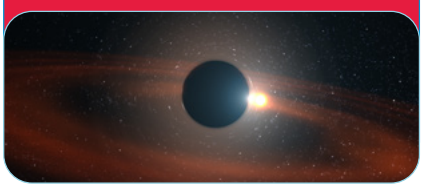
A study with the participation of CSIC may have discovered the answer to a mysterious stellar event

09/12/2024

ICE-CSIC holds the first GLITTER school for predoctoral researchers working in Earth Observation

11/12/2024

Astronomers detected a burst caused by a black hole swallowing a star



12/12/2024

A team of astronomers finds clues on the magnetism of a new kind of M dwarf

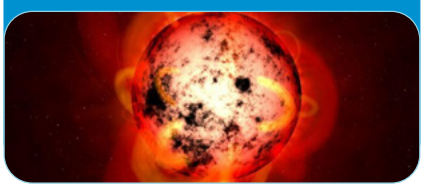


Image Credits

ICE-CSIC participation in Missions and Experiments Infographic (pages 27 and 28)

1. **ARIEL**
   Ariel telescope. Credits: ESA/STFC RAL Space/UCL/UK Space Agency/ATG Medialab.

2. **CARMENES**
   The 3.5-metre telescope of the Calar Alto Observatory, from where the CARMENES instrument operates. Credits: IAA-CSIC.

3. **CTAO**
   CTAO-South site. Credits: CTAO ERIC.

4. **Euclid**
   Illustration of the Euclid space mission. Credits: ESA/Euclid/Euclid Consortium/NASA. Background galaxies: NASA, ESA, and S. Beckwith (STScI) and the HUDF Team.

5. **LISA**
   The three LISA spacecraft will be placed in orbits forming a triangular configuration, with the center 20° behind the Earth and each side measuring 5 million km. (The figure showing the formation is to scale). Credits: NASA.

6. **PAU**
   PAUCam. Credits: PAUCam.

7. **PAZ**
   Artistic view of the PAZ Low Earth Orbiter, launched in February 2018. This satellite hosts the Radio Occultation and Heavy Precipitation experiment aboard PAZ (ROHP-PAZ), testing the capability of polarimetric radio occultation signals to sense precipitation events. Credits: Hisdesat.

8. **PLATO**
   Artist's impression of ESA's PLATO spacecraft. Credits: ESA/ATG Medialab.

9. **ARRAKIHS**
   Simulation of the halo of one of the galaxies that will be observed in the ARRAKIHS mission. Credits: Alex Camazón (ARRAKIHS Consortium).

10. **DES**
    Blanco Telescope located at the Cerro Tololo Inter-American Observatory. Credits: Andreas Papadopoulos.

11. **DESI**
    Blanco Telescope at the Cerro Tololo Inter-American Observatory in Chile. Credits: Reidar Hahn, Fermilab.

12. **HydroGNSS**
    Artist's impression of the HydroGNSS satellite in orbit. Credits: SSTL.

13. **LIGO**
    LIGO. Credits: LIGO.

14. **LST**
    LST. Credits: LST.

15. **CHEOPS**
    Artist's impression of Cheops, the Characterising Exoplanet Satellite, with an exoplanet system in the background. Credits: ESA/ATG Medialab.

16. **DART**
    Illustration of the DART mission. Credits: NASA/Johns Hopkins APL.

17. **Einstein Probe**
    Einstein Probe. Credits: CAS/ESA/Max Planck Society.

18. **Einstein Telescope**
    Einstein Telescope artist's impression. Credits: Einstein Telescope Collaboration.

19. **eXTP**
    Baseline design of the eXTP satellite. The payload includes 9 (SFA) and 4 (PFA) X-ray telescopes, 40 LAD modules, and 3 WFM camera pairs. Credits: eXTP.

20. **Fermi**
    Illustration of the Fermi Gamma-ray Space Telescope, which has been studying the extreme universe for a decade. Credits: NASA's Goddard Space Flight Center/Conceptual Image Lab.

21. **HERA**
    Hera scans DART's impact crater. Credits: ESA. Image taken from the video "Hera: ESA's Planetary Defence Mission".

22. **LSST**
    LSST. Credits: LSST.

23. **LS4**
    LS4. Credits: LS4

24. **NewAthena**
    An artistic view of the NewAthena space observatory. Credits: ESA/IRAP/CNRS/UT3/CNES/Fab&Fab. Composition: ACO.

25. **ROMAN**
    Spacecraft visualization of the Nancy Grace Roman Space Telescope. Credits: GSFC/S.

26. **SKAO**
    SKAO. Credits: SKAO.

ICE-CSIC News infographic (pages 94 and 95)

1. **9/1/2024**
Einstein Probe artist impression. Credits: Chinese Academy of Sciences.

2. **25/1/2024**
Artist's impression of the LISA mission satellites in the solar system observing gravitational waves from a distant galaxy. Credits: University of Florida / Simon Barke (CC BY 4.0).

3. **28/3/2024**
Álex Alarcón González receiving the Junior Leader postdoctoral fellowship. Credits: La Caixa Foundation.

4. **4/4/2024**
DESI has created the largest three-dimensional map of our universe to date. Earth is at the center of this thin section of the full map. In the enlarged section, it is easy to see the underlying structure of matter in our universe. Credits: Claire Lamman/DESI Collaboration; custom color map package by cmastro.

5. **16/4/2024**
The director of the Institut d'Estudis Espacials de Catalunya (IEEC) and researcher at the Institute of Space Sciences (ICE-CSIC) Ignasi Ribas. Credits: César Hernández/CSIC.

6. **18/4/2024**
Banner ALLIES project. Credits: ALLIES project.

7. **23/4/2024**
Members of the LISA Consortium Constitutional Council during the meeting on 15 April 2024. Credits: Carlos F. Sopuerta.

8. **27/4/2024**
An image of supernova remnant Puppis A in X-ray light, taken as part of the test and calibration campaign of Einstein Probe. Credits: Chinese Academy of Sciences.

9. **29/4/2024**
Sahrawi girl attending a VR experience in the framework of the GalileoMobile activities at the Sahrawi Refugee Camps near Tindouf in 2019. Credits: GalileoMobile.

10. **3/5/2024**
Attendees of the Euclid Spain Meeting 2024. Credit: ICE-CSIC.

11. **6/5/2024**
Artist's impression of a supermassive black hole in an active galaxy. Credits: ESA/AOES Medialab.

12. **23/5/2024**
Euclid's new image of star-forming region Messier 78. Credits: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi; CC BY-SA 3.0 IGO or ESA Standard Licence.

13. **3/6/2024**
Simulation of a stellar stream in the halo of a galaxy to be observed by Arrakihs. Credits: Arrakihs Consortium.

14. **5/6/2024**
The LISA mission will detect gravitational waves in space using three spacecraft flying in a triangular formation. Lasers fired between the satellites, shown in this artist's concept, will measure how gravitational waves alter their relative distances. Credit: AEI/MM/ Exozet.

15. **10/6/2024**
The new ICE-CSIC Managing Team (from left to right): Mar Mezcua (scientific deputy director), Aldo Serenelli (director) and Serni Ribó (technical deputy director). Créditos: ICE-CSIC.

16. **11/7/2024**
ICE-CSIC researcher Nanda Rea. Credits: César Hernández/CSIC Comunicación.

17. **25/7/2024**
Scheme of the GLITTER concept. Credits: GLITTER Consortium, using images from Copernicus S3A, Galileo.

18. **30/7/2024**
The asteroid Dimorphos was captured by NASA's DART mission just two seconds before the spacecraft struck its surface. Credits: NASA/Johns Hopkins APL.

19. **6/8/2024**
Frames from four videos used in the article to study the SPMN180524F superbolide. Credits: Eloy Peña-Asensio et al.

20. **14/8/2024**
In this artist's interpretation, the basics of a pulsar are color-coded. In white is the neutron star. Its powerful magnetic field is shown in blue. The north and south poles of that magnetic field, and the directions from which the pulsar's beams shoot, are in yellow. And in red is the axis of rotation of the star. That axis is offset from the beam, which is why when the star spins, the beam sweeps past us. Credit: B. Saxton, NRAO/AUI/ NSF.

21. **9/9/2024**
Group picture of institute's directors accepting the Severo Ochoa and María de Maeztu accreditations, including Diego Torres (third to the right) on behalf of ICE-CSIC, with the Science Minister Diana Morant. Credits: Ministry of Science,

Innovation and Universities (MICIU).

22. **13/9/2024**
Group picture with the teaching staff from the Gabriel Castellà i Raich school, scientific-technical staff from the ICE-CSIC and staff from the Bofill Foundation. Credits: ICE-CSIC.

23. **7/10/2024**
Computer rendering of ESA's Hera mission approaching the asteroid Dimorphos. Credit: ESA-Science Office.

24. **25/10/2024**
Group picture of the attendees to the LISA Spain Meeting 2024. Credits: ICE-CSIC.

25. **4/11/2024**
Artist's Impression of the fastest-feeding black hole in the early Universe. Credits: NOIRLab/NSF/AURA/J. da Silva/M. Zamani.

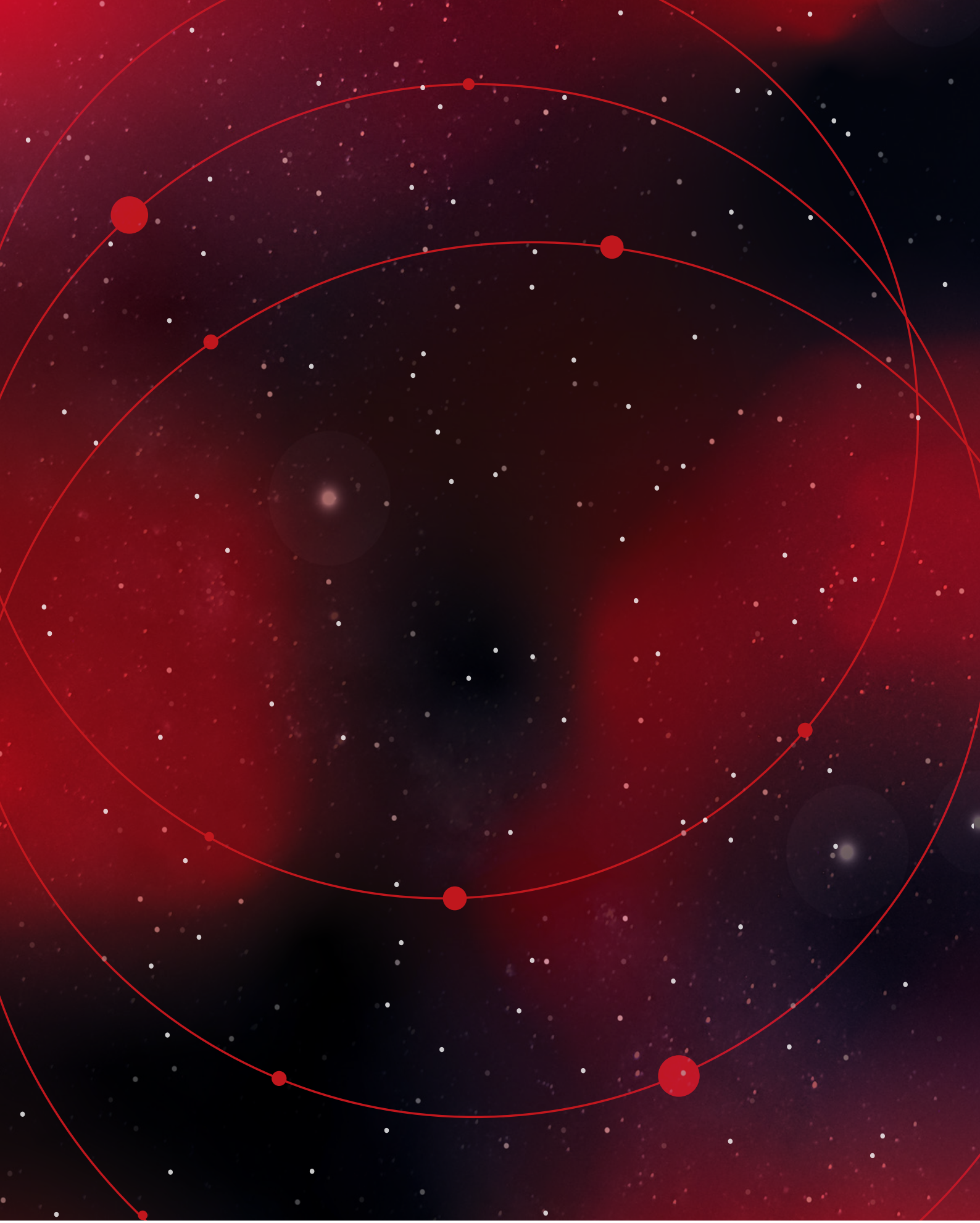
26. **20/11/2024**
DESI observes the sky from the Mayall Telescope, shown here during the 2023 Geminid meteor shower. Credit: KPNO/NOIRLab/NSF/AURA/R. Sparks.

27. **26/11/2024**
The radio signal was detected in data from the MurchisonWidefield Array radio telescope, located at Inyarrimanha Ilgari Bundara, CSIRO's Murchison Radio-astronomy Observatory. Credit: ICRAR/Curtin.

28. **9/12/2024**
Group picture of some of the in-person attendees to the first Doctoral Network GLITTER school. Credits: ICE-CSIC.

29. **11/12/2024**
Recreation of a burst, identified as CSS161010, in which a small black hole swallows a star. Credits: Gabriel Pérez/IAC.

30. **12/12/2024**
An illustration of an M-dwarf star covered in starspots. Cropped version of image from NASA/ESA/STScI/G. Bacon.



CSIC
Consejo Superior de Investigaciones Científicas

Institute of Space Sciences

25th Anniversary

Excelencia María de Maeztu

IEEC