INSTITUTE OF SPACE SCIENCES

Annual Report 2023

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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.

Institute of Space Sciences

EXCELENCIA MARÍA DE MAEZTU

CSIC

IEEC

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The ICE-CSIC 2023 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

2023 has been at ICE-CSIC a year for consolidating many of the efforts that have been possible thanks to the foundations laid out in previous years.

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

But let me first use this space to thank Diego F. Torres who stepped down as the Institute's Director after eight years. Under his helm, ICE-CSIC developed, grew, and consolidated its place as a centre of excellence in experimental and theoretical research in space sciences. Personally, it has been a pleasure to work closely with him as Deputy Director for over three years. Diego, on behalf of the whole Institute, I would like to express our deepest gratitude for your tireless work through these years.

Our second year as a 'María de Maeztu' research centre has allowed the Institute to see significant growth, both in terms of personnel, the upgrade of our facilities, and to deploy internal programmes for further developing the abilities of our researchers. Over the year, the ICE-CSIC family reached over 150 people, including four new Faculty members.

Research at ICE-CSIC continued excelling with a total of 289 refereed publications by ICE-CSIC personnel in 2023, 95% of them in 1st quartile journals. 2023 was also very important regarding our participation in space missions. An important milestone was the launch of ESA's Euclid in July, a mission where ICE-CSIC has been involved since 2006 on its initial concepts. ICE-CSIC has been responsible for the development of the Filter Wheel Assembly of the NISP instrument, one of Euclid instruments, and for generating cosmological simulations for the science exploitation. Now that Euclid is up and running, our Institute continues its key role in the mission to explore the dark Universe.

In 2023 we have also centred our efforts on team building and improving the Institute's work environment. At the beginning of the year, we celebrated our 4th Strategy Retreat at the Santa Maria de Montserrat Abbey. For three days, all Institute's personnel were able to bond while at the same time learning about each other's work as well as discussing our future. Another important step during the year to ensure a safe and responsible work environment was the development of the ICE-CSIC Code of Conduct by the Equity Committee.

As a new chapter unfolds at ICE-CSIC, we enter an exciting period in which the Institute will renew its internal structures to adapt to the development and growth of the last few years, and will think and establish new strategies for the next five years.

Aldo Serenelli, ICE-CSIC Acting 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 model better 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 (UAB) 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.

1.2. ICE-CSIC in 2023

The year 2023 was a remarkable year for ICE-CSIC.

Diego F. Torres, our director since 2016, stepped down from his position in early September. During his time as director, the Institute grew substantially and consolidated its place as a centre of excellence in experimental and theoretical research in space sciences [see Section 1.3 for more information on Diego Torres' Directorship]. While a new director was appointed, ICE-CSIC Deputy Director Aldo Serenelli served as Acting Director since September 2023.

The Institute kept growing during 2023 with 173 people working at the Institute during the year, for a total of 155 ICE-CSIC personnel as of 31 December 2023. From those, we were happy to welcome four new Faculty members (Guillem Anglada, Lluís Galbany, Sascha Husa and Daniele Viganò).

Group picture of ICE-CSIC personnel at the Christmas party in December 2023.
Credits: ICE-CSIC.

In 2023, our research continued excelling in many areas of astronomy and Earth observation with a total of 289 refereed publications by ICE-CSIC researchers. The highlights include how the CARMENES project boosted the number of known planets in the solar neighbourhood with the discovery of 59 exoplanets (Ribas et al. 2023); the discovery of supermassive black holes in dwarf galaxies when the Universe was much younger than it is today, a very unusual finding since until now very few cases have been discovered in the local Universe (Mezcua et al. 2023); the finding of an active stellar corpse, possibly a black hole or neutron star, which was the likely source of repeated energetic flares never seen before (Ho et al. 2023); the finding of a new type of stellar object that challenges our understanding of the physics of neutron stars (Hurley-Walker et al. 2023); the first analyses of the NASA's DART mission, a mission dedicated to demonstrating the method of asteroid deflection of a potentially hazardous asteroid (Cheng et al. 2023; Li et al. 2023); and the detection of six planets orbiting their central star in sync showing that the planetary system has not suffered major changes since its formation (Luque et al. 2023).

This year was also very important regarding ICE-CSIC's participation in space missions. As a highlight, in early July, ESA's EUCLID satellite mission was launched. EUCLID will create the largest and most accurate 3D map of the Universe to understand how large-scale structure formed and evolved over cosmic history. This is a very important milestone for our institute, since ICE-CSIC has been working for

over 15 years in the mission. The Institute has been responsible, together with IEEC and the Institut de Física d'Altes Energies (IFAE), for the development of the Filter Wheel Assembly of the NISP instrument aboard Euclid. In addition, it was responsible for the mission's cosmological simulations that have served to study its optimisation and prepare the software for data processing and analysis. Euclid's first full-colour images released in November 2023 are the sharpest ever across such a large section of the sky and looking so far into the distant Universe, showcasing Euclid's full potential.

The ICE-CSIC Advanced Engineer Unit (AEU) has also been going through a lot of changes to offer better services to the engineers and experimental researchers working at the Institute. In this respect, there have been significant improvements at the AEU in 2023. On one side, there have been substantial renovations in the laboratories, such as the microscopy clean room, which also includes now a vacuum Fourier spectrometer. Another important aspect has been the purchase of equipment, for instance an atomic clock gives now service for all the laboratories.

New vacuum fourier spectrometer at the Microscopy Clean Room laboratory.
Credits: Josep María Cirera/ICE-CSIC.

ICE-CSIC continued providing opportunities in 2023 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 15 PhD students during the year, of a total of 44 PhD students now. Another important matter was the organisation of the 6th edition of the ICE-CSIC Summer School, which welcomed around 40 early-career researchers from 14 different countries who spent two weeks at the Institute learning about the Life Cycle of Dust from renowned experts in the field.

This was also a great year regarding grants and contracts managed by the Institute, with the acquisition of 17 new projects and a total funding of 5.05 million euros. This included the coordination of the Marie Skłodowska-Curie Actions (MSCA) Latin American Chinese European Galaxy Formation Network (LACEGAL) and two Spanish National Plan Grants for coordinating the Spanish contribution of Euclid and LISA missions, respectively.

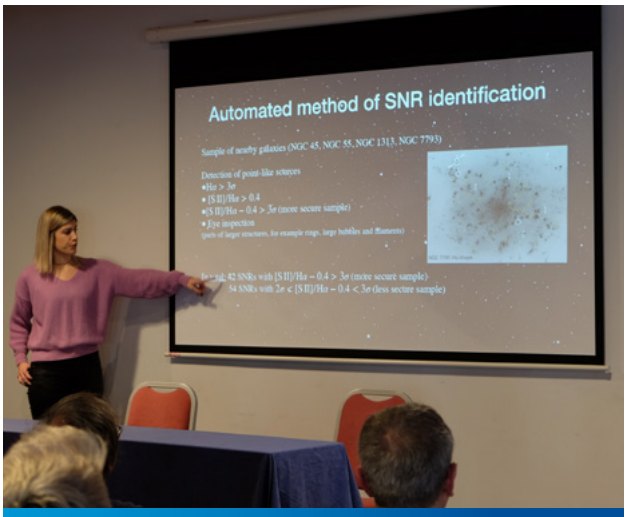
Group picture of the Chinese delegation of eXTP, together with ICE-CSIC researchers and engineers.
Credits: ICE-CSIC.

ICE-CSIC hosted seven international workshops and meetings during the year, including a meeting with a Chinese delegation from the eXTP satellite Consortium, and the organisation of scientific workshops for ARRAKIHS, Athena, Euclid and LISA missions. These meetings served to advance the work of key aspects of these space missions.

Friday always means a seminar, followed by a pizza, at ICE-CSIC. 2023 continued this tradition with the organisation of 31 pizza seminars with speakers both from inside and outside the Institute covering all fields of astronomy and space sciences. The Institute also organised two colloquia welcoming the micro-meteorite hunter expert Jon Larsen and ASTRON director Prof. Jessica Dempsey. It is also worth mentioning the start of the PhD Seminar series, a monthly series of talks for and by PhD students.

As part of the María de Maeztu Thematic Core programme of the Institute, we received the visit of Prof. Shin'ichi Nojiri (Nagoya University) who stayed at ICE-CSIC for one month hosted by Emilio Elizalde and Sergei Odintsov and worked on the topic of modified gravity theories. As part of the visit, a series of special conferences on the topic were organised, with the participation of Dr. Diego Sáez-Chillón Gómez (Valladolid University) and Prof. Jaume Haro of BarcelonaTech (UPC). As a result of these activities, three peer reviewed articles have already been submitted to Q1 journals and are at different stages of the reviewing or publication process.

2023 was also very important for ICE-CSIC to look into the future and foster team building, since the Institute held its 4th Strategy Retreat at the end of January in Santa Maria de Montserrat Abbey, near Barcelona. For three days, all ICE-CSIC personnel learnt about the general status of the Institute and received updates on the Institute's departments, current space missions, technology transfer opportunities, as well as attended talks by senior researchers and engineers, postdoctoral researchers, and PhD students discussing their research and work.



ICE-CSIC postdoctoral researcher María Kopsacheili giving a talk about her work at the ICE-CSIC strategy retreat in January 2023.
Credits: ICE-CSIC.

Another important milestone for the Institute was the development and approval of the ICE-CSIC Code of Conduct, which was led by the ICE-CSIC Equity Committee. This comprehensive document lays out the norms, rules, and proper practices expected from ICE-CSIC members to ensure that all members can thrive as individuals and as scientists, regardless of age, race, ethnicity, religion, gender identity or expression, sexual orientation, and disability status.

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 the launch of an Instagram account as well as a quarterly newsletter; a specific campaign around the Euclid launch; the Institute's participation in the Magnet Alliance with the Gabriel Castellà i Raich school in Igualada (Barcelona) to fight school segregation; the participation in new initiatives such as the Amanar summer programme working with Sahrawi children and the ESA CESAR programme contributing in online teacher training, as well as the organisation of special activities for the CSIC Science and Technology Week and the European Researchers' Night.

A talk during the ICE-CSIC strategy retreat in January 2023.
Credits: ICE-CSIC.

Key figures 2023

155 MEMBERS (as of 31 December 2023)

4 New faculty members

58 International members

289 peer-reviewed publications

95% of publications in 1st quartile journals

2.635 TOTAL CITATIONS

5 publications in Nature

17 NEW projects

5.05 MILLION EUR Funding new projects

49 Active projects

>100 Seminars & outreach talks

31 PIZZA seminars

1 award

17 Press releases

477,000 people reached by ICE-CSIC communication actions

>523 media impacts in Spanish media

84.5 MILLION people extended reach with media coverage

1.3. Diego F. Torres Directorship (2016 - 2023)

Diego F. Torres, an ICREA Research Professor at ICE-CSIC and IEEC, became ICE-CSIC's director in March 2016. During his directorship, the Institute grew substantially and consolidated its place as a centre of excellence in experimental and theoretical research in space sciences. Among his achievements, he established a new management and organisational scheme, created new distributed executive structures, produced written internal regulations, organised the Advanced Engineering Unit, and established the ICE-CSIC International Advisory Committee.

Diego F. Torres, ICE-CSIC researcher and director from 2016 to 2023.
Credits: Departament de Recerca i Universitats, Generalitat de Catalunya.

In the eight years of his directorship, the Institute experienced a substantial growth in personnel. For instance, the number of tenured scientists increased from 14 to 29 (more than 100%) and the administration staff by more than 200%, due to the creation of new services (like the Communication and Outreach Office or the laboratory management support) and the enhancement of others.

This was possible thanks to the evolution of the Institute's resources and management grants. Grants and contracts managed by ICE-CSIC averaged 5.5 million euros per year in this period, and grew from 4.2 in 2016 to 7.37 million euros in 2022. Among those, ICE-CSIC was recognised as one of the top research centres in Spain and received the María de Maeztu Seal of Excellence from the Spanish Government in 2021, which included an award of 2.8 million euros (including funding for PhD students) and an EU Next Generation of 1.8 million euros. Concurrently, the average yearly amount in contracts with industry or ESA that was acquired by our personnel in the period increased five-fold compared to 2016. More than 6 million euros were acquired and invested to improve ICE-CSIC's global infrastructures and research in this period.

Under Torres' directorship, ICE-CSIC created its Summer School Programme (over 300 international students during its six editions so far), the ICE-CSIC Strategy retreat (5 sessions organised, 2 days discussion about ICE-CSIC research and future), strengthened participation in the Postgraduate Programme of High Energy Physics, Astrophysics and Cosmology (half the students continue in ICE-CSIC every year, with the Institute offering several bridge fellowships for students to continue PhD studies), and started several other programmes, like the Thematic Cores, Outgoing professorships, Students and Fellows best paper awards, and more. Off-topic seminars and Debate series were also created to foster ICE-CSIC's social life.

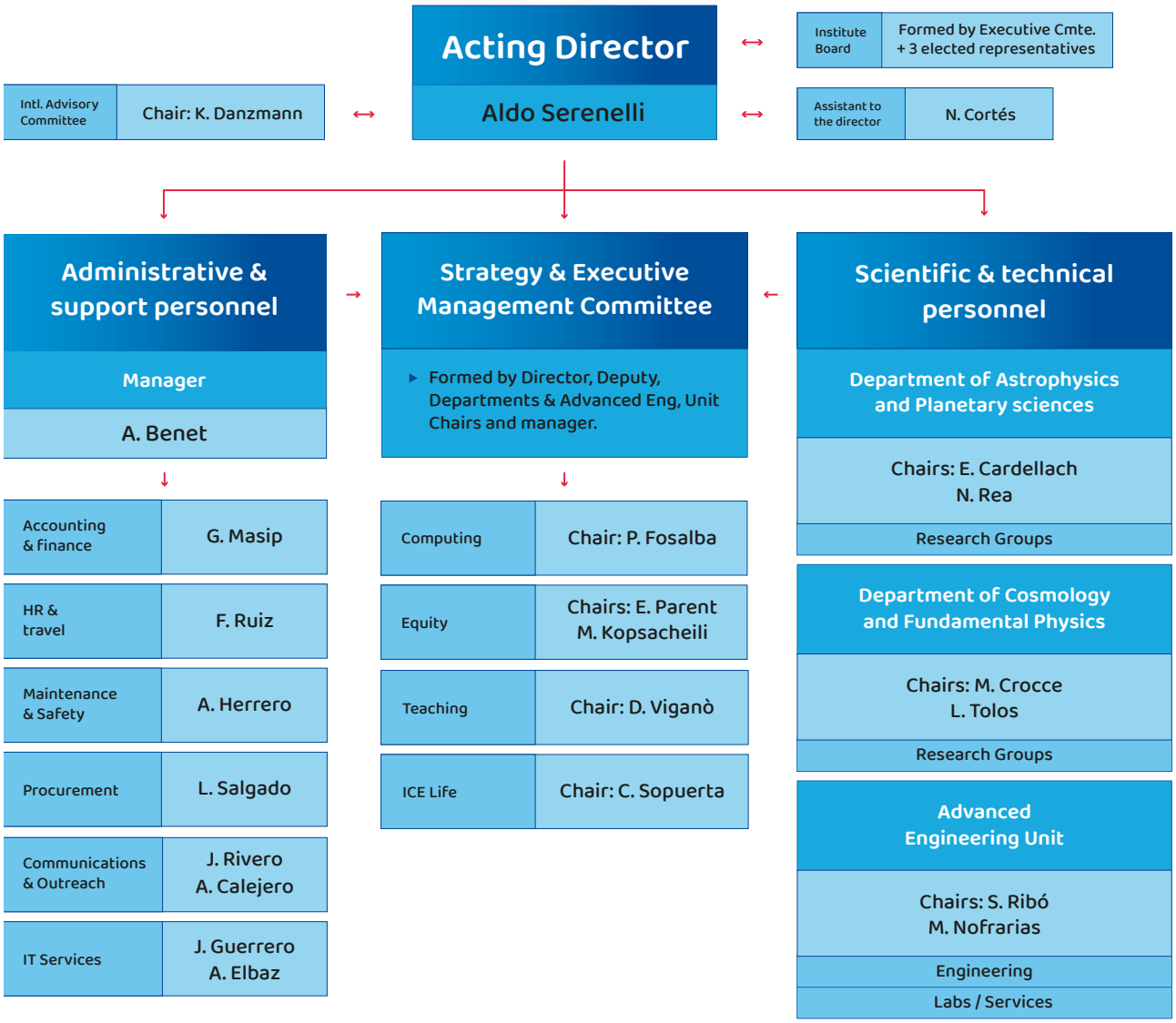
Another important aspect of his tenure as ICE-CSIC director has been fostering the public engagement actions of the Institute with the creation of the ICE-CSIC Communication & Outreach Office and the participation of several public engagement initiatives, most notably the Magnet programme, where ICE-CSIC collaborates in the 2021-2025 period with a school in Igualada (Spain) to fight school segregation using astronomy. In addition, during his directorship, the Institute has advocated the importance of equity actions, including establishing gender balance on the Institute's Strategy Committee as well as in decision bodies of all internal positions; the creation of the ICE-CSIC Equity Committee and posts of PhD & Postdoc representatives; and the promotion of the bottom-up 'ICE-CSIC Code of Conduct', approved by the Institute's Board.

ICE-CSIC is today at the forefront of research in Spain, usually found at the very top places in scientific productivity, both per research and as a whole, regardless of the institutional size.

2. Management

ICE-CSIC is organised in two departments, the Department of Astrophysics and Planetary Sciences (APS) and the Department of Cosmology and Fundamental Physics (CFP); and a technical unit, the Advanced Engineering Unit (AEU). At a formal scientific level, there are about ten research groups at the Institute, typically composed of about 10+ members, with 2-4 Faculty in each of them. Research groups are indeed fluid at ICE-CSIC, and it is common to see cross-interaction among members from different formal groups, even of different departments.

Besides these scientific units, three formal bodies structure the centre: the Director's Office, the Board, and the Strategy Committee. Finally, we have several other committees aimed to coordinate different aspects of the Institute.

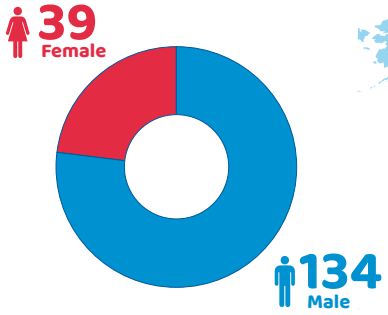


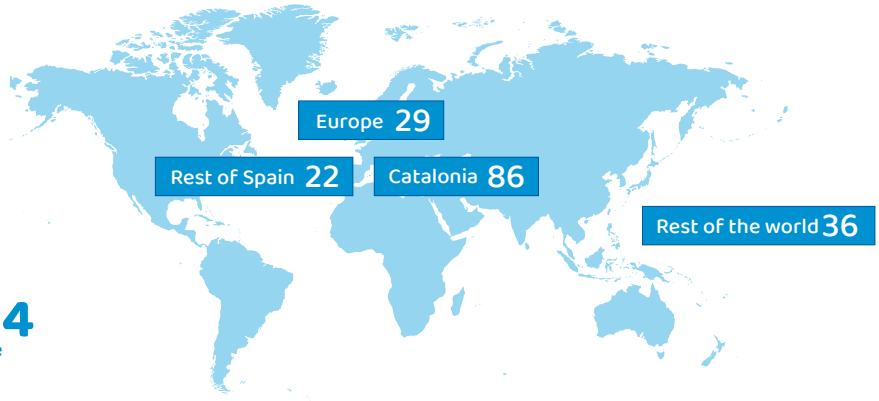
3. People

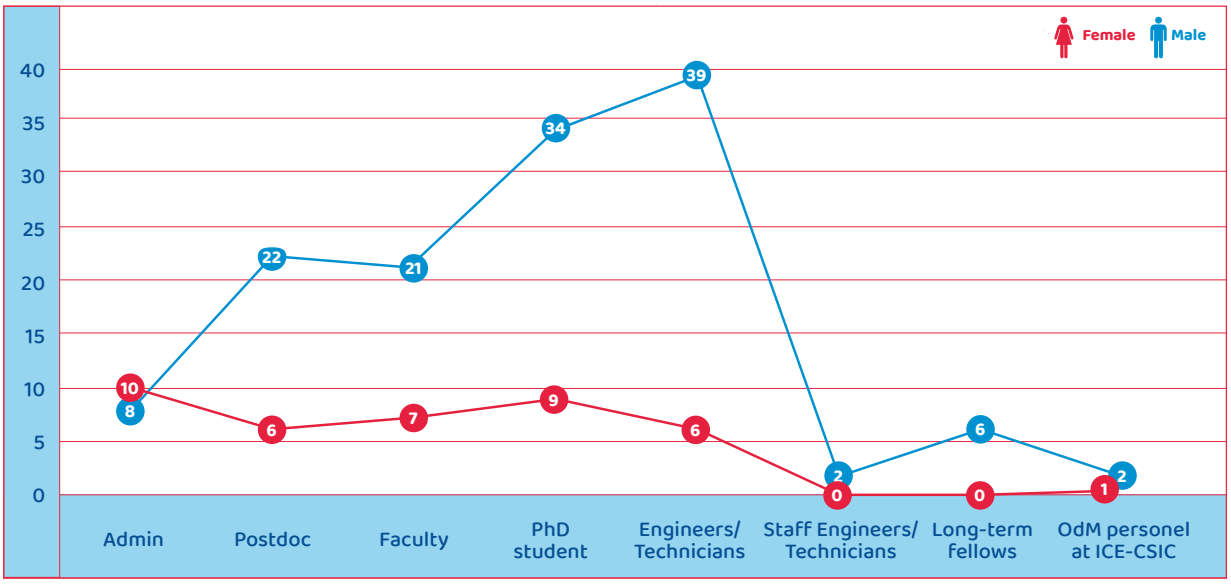
We are a diverse and international team of researchers, engineers and support staff. Throughout 2023, 173 people worked at ICE-CSIC, being the total number of personnel of 155 people as of 31 December 2023. This is an increase of 25% in comparison with the end of 2022. The data shown in the graphs and the list in this section reflects ICE-CSIC's personnel during the year 2023.

ICE-CSIC researchers discussing new findings. From left to right: Konstantinos Kovlakas, Stefano Ascenzi, Abubakr Ibrahim, Nanda Rea, Davide de Grandis and Francesco Coti Zelati. Credits: César Hernández.

3.1. Personnel







Administration

Barreto, Leonardo

Bayona, Albert (until July 2023)

Benet, Àngels

Calejero, Alba

Cortés, Noemí

Egea, Nerea (since July 2023)

Elbaz, Ángel

Enriquez, Froilan (February-December 2023)

Góngora, Jorge (until June 2023)

Guerrero, Josep

Herrero, Ángel

Masip, Guadalupe

Pino, Cristina (since June 2023)

Ripoll, Maribel

Rivero, Jorge (since February 2023)

Ruiz, Fina

Salgado, Laura

Stanemir, Andra (since October 2023)

Postdoctoral Fellows

Akgün, Taner (until November 2023)

Ascenzi, Stefano (until August 2023)

Breton, Michel-Andrès

Celora, Thomas (since November 2023)

De Grandis, Davide (since May 2023)

De Sarkar, Agnibha (since November 2023)

Dehman, Clara

Del Sordo, Fabio

Gouyou Beauchamps, Sylvain

Graber, Vanessa

Gutiérrez, Claudia Patricia (since May 2023)

Herrera, Yago

Khurshudyan, Martiros

Kopsacheili, Maria

Kovlakas, Konstantinos

Lenzi, Michele

Marino, Alessio

Martin, Ivan (since September 2023)

Mestre, Enrique (since February 2023)

Meyer, Dominique Marc Antoine (since December 2023)

Morales, Juan Carlos

Morata, Oscar (since June 2023)

Müller, Tomás

Navarrete, Felipe

Parent, Emilie

Parimbelli, Gabriele

Perger, Manuel

Ramakrishnan, Sujatha (since December 2023)

Faculty

Anglada-Escudé, Guillem

Cardellach, Estel

Castander, Francisco Javier

Crocce, Martin

Elizalde, Emilio

Fosalba, Pablo

Galbany, Lluís

Gaztañaga, Enrique

Girart, Josep Miquel

Hernanz, Margarita

Husa, Sascha

Isern, Jordi

Kemper, Francisca

Manuel, Cristina

Mezcua, Mar

Nofrarias, Miquel

Odintsov, Sergei D.

Rea, Nanda

Ribas, Ignasi

Ribó, Serni

Rius, Antonio

Serenelli, Aldo

Sopuerta, Carlos

Tolos, Laura

Torrelles, José María

Torres, Diego F.

Trigo-Rodríguez, Josep M.

Viganò, Daniele

Staff Engineers/ Technicians

Colomé, Josep

Martín, Víctor

Long-term fellows

Alarcon, Alex (since November 2023)

Coti Zelati, Francesco

Li, Weiqiang

Padullés, Ramon

Patruno, Alessandro

Sánchez, Álvaro

Engineers/Technicians

Aguilar, Eduard (since July 2023)
Álvarez, Daniel
Ballber, Pau
Barnera, Carla (since April 2023)
Bonastre, Biel (April-September 2023)
Campos, Néstor
Canal, Miquel
Canalda, Xavier [1]
Carmona, Alex (since March, 2023)
Casadesús, Eugeni (until April 2023)
Casas, Ricard
Cirera, Josep Maria
Costa, Jean Marc (since September 2023)
Esteva, Ignasi (since March 2023)
Farràs, Sílvia
Ferentz, George
Ferrer, Daniel (until April, 2023)
Ferres, Patrícia (until March, 2023)
Gálvez, José-Luis
García, Alberto
García, Pedro (until May 2023)
Gómez, Jan (until May 2023)
Herencia, Daniel (since September 2023)
Hormaetxe, Ander (until August 2023)
Karimbu Vallappil, Arshad (since July 2023)
Komorowski, Przemyslaw (since December 2023)
Llauradó, Blanca (until August 2023)
Metge, Jean-Jacques (until August 2023)
Montón, Màrius (until August 2023)
Montoro Martínez, Álvaro
Morales, Jordan (until August 2023)
Nakhjiri, Nariman
Oliveras, Santi
Pérez, Ana
Reydan, Ahmed Reydan (since October 2023)
Roma, David
Salvans, Josep
Serrano, Santiago
Serrano, Daniel
Sierra, Carles
Sisteré, Sofia
Soldevila, David
Takhyane, Ibrahim
Vallés, Ramon
Verderi, Axel

PhD students

Alburai, Alaa (since November 2023)
Alemany, Marc
Baghkhani, Zahra (since April 2023)
Blanco, Jordi (since December 2023)
Blázquez, Carles
Camacho, Benjamín
Camacho Ciurana, Gisela Cristina (since December 2023)
Coloma Nadal, Jose María (since Decembre 2023)
Çoban, Ömer Faruk
Cross, Dane (until May 2023)
D'Onofrio, Simone
Díaz, Pedro
Du, Hao
Elias, Albert
Eróstegui, Alejandro (since February 2023)
Fernández de Alarcón Muguruza, Pablo (since December 2023)
Gambardella, Giosuè (since December 2023)
Gascón, Carlos (until May 2023)
González, Guillermo
Gonzalez Bañuelos, Maider (since october 2023)
González Díaz, Raúl
Grèbol, Pau (since March 2023)
Gualani, Vivek
Hernández, José Luis
Huang, Bo
Ibrahim, Abubakr
Íñiguez, Daniel
Jiménez, Cristina
Kaur, Simranpreet
Martin, Iván (since September 2023)
Navarro, David
Pardo, Celsa
Paz, Antía
Peña Asensio, Eloy
Peng, Jilun
Phan, Kim
Rodríguez, Carlos
Rodríguez, Víctor (since December 2023)
Ronchi, Michele
Soriano, Clàudia
Untzaga San Vicente, Julen (since September 2023)
Viglione, Cristian Nery (since September 2023)
Zhang, Wei (since September 2023)

Montsec Observatory (OdM) personnel at ICE-CSIC

Herrero, Enrique
Baroch, David (until September 2023)
Martí, Laura

[1] He is also doing his PhD at the Institute.

3.2. New Faculty Members

Guillem Anglada-Escudé

Guillem Anglada-Escudé earned his PhD in 2008 from the Universitat de Barcelona (UB), Spain, and worked as a postdoctoral researcher in different institutions, such as the Carnegie Institution for Science in Washington D.C., USA; the Institute for Astrophysics, Georg-August-Universität Göttingen, Germany; and the Queen Mary University of London, United Kingdom. In 2019, he joined the ICE-CSIC as a Ramón y Cajal Fellow to work in the Exoplanets research group. Since 2023, he is a tenured scientist at ICE-CSIC. His research areas are exoplanet detection, data analysis, instrumentation and planetary exploration. He is involved in different space missions such as ARIEL and CARMENES.

In 2016, he led the collaboration that reported the discovery of Proxima b, the nearest exoplanet to the Solar System, which happens to have some Earth-like characteristics. The discovery of Proxima b was one of the scientific results most acclaimed in 2016. In addition, he has participated in a number of collaborations obtaining high impact exoplanet results, such as numerous contributions to the CARMENES survey, and other high profile nearby exoplanets; such as AU Mic b, the nearest young star with a transiting planet; or the gas giants around GJ 3512 which presented a paradigm shift in planet formation scenarios.

Another collaboration he was part of is the Red Dots collaboration, which consists of performing similar searches to other very nearby red dwarf stars, some of them performing real time data-releases, and using the support of numerous pro-am astronomers from all over the world. This effort led to high profile discoveries such as the nearest compact multi-planet system GJ 887, or the trio of terrestrial planet candidates around GJ 1061, as Barnard's Star b planet candidate.

Guillem Anglada-Escudé.
Credits: Xavier Lapuente/ICE-CSIC.

He has co-led the The Sustainable Offworld Network (SONet), which is a multidisciplinary effort to develop and explore long-term sustainability of human activities in space. Their project of a sustainable city model on Mars called Nüwa was a finalist in the Mars Society – Mars City State competition in 2020.

As he is interested in science communication and engaging with the public, he was part of the initiative Pale Red Dot, which received numerous awards abroad. He was also a member of the IAU100 NameExoworlds competition, a global effort to engage the general public in astronomy and science.

His work in exoplanet detection has placed him on the "Nature 10" list of the most influential scientists of 2016. He was also included on the "Time 100" list of 2017, and was selected as European Young Leader 2017 by the think tank Friends of Europe, among other recognitions.

Lluís Galbany

Lluís Galbany is an astrophysicist and observational cosmologist. He earned his degrees in Physics in 2006 and Economics in 2023 from the Autonomous University of Barcelona, Spain, where he also obtained his doctorate in Physics at the Institut de Física d'Altes Energies (IFAE) in 2011. His PhD on type Ia supernova cosmology was the first one developed in a Spanish institution on this topic.

He worked as a postdoctoral researcher at the Centro de Astrofísica (CENTRA) in Lisbon, Portugal. Subsequently, from 2013 to 2016, he held the prestigious Fondecyt postdoctoral fellowship at the Department of Astronomy of the University of Chile, where he had the privilege to collaborate with Professor Mario Hamuy. Further expanding his horizons, he joined the Department of Physics and Astronomy at the University of Pittsburgh, USA, as a postdoctoral researcher from 2016 to 2019. Right after, he became a Marie Skłodowska-Curie fellow at the Department of Theoretical Physics and Cosmos at the University of Granada, Spain. Since 2021 he

has been a Ramon y Cajal fellow and now a Científico Titular at ICE-CSIC where he leads the Supernova Group, which focuses its research primarily on the study of the physics of supernovae and its application in observational cosmology.

Throughout his career, Lluís Galbany has consistently demonstrated a firm passion for scientific exploration and a deep commitment to the advancement of knowledge in his investigations. His research has been concerned with key observational aspects of supernova science that have a direct impact on other areas of astrophysics such as stellar evolution, galaxy enrichment, and cosmology. His main research line is focused on investigating the local environments where supernovae explode, characterising their properties, and leveraging this knowledge to constrain supernova progenitor systems and reduce systematic uncertainties in both type Ia and type II supernova brightness standardisation. Lluís is also a full member of ongoing and next-generation collaborations in supernova cosmology such as La Silla Southern Supernova Survey (LS4), the Legacy Survey of Space and Time (LSST) and the Nancy Roman Space Telescope Supernova Survey. By combining the wide range in lookback time, these three experiments will yield groundbreaking results in the field.

Furthermore, Lluís Galbany has been a dedicated mentor, fostering the growth and development of young scientists. This is evident in his track record of supervising Bachelor and Master's students, along with his leadership of the recently formed supernova

Lluís Galbany.
Credits: Xavier Lapuente/ICE-CSIC.

research group at ICE-CSIC, which consists of six PhD students under his guidance and three postdoctoral researchers. This group is the sole one in Spain exclusively dedicated to supernova observations and ranks among the largest in our community led by a single researcher.

In addition to the numerous fellowships and competitive grants he has received, L. Galbany has actively engaged in outreach activities throughout his career. He has offered media interviews, delivered talks to various associations and schools representing diverse sociological backgrounds, and organised numerous astronomy-related activities in schools. He initiated several outreach projects, such as the 'Ciencia amb Tirador' series of talks at bars and the 'La Veu Còsmica' podcast on science and art.

Sascha Husa

Sascha Husa studied at the University of Vienna, Austria, where he obtained his PhD in 1998 under the supervision of Robert Beig. His thesis developed new methods for the numerical solution of the constraint equations of general relativity for black holes, and established a path that would eventually lead Husa from mathematical relativity to observing gravitational waves.

Afterwards, he started a postdoctoral position with the Pittsburgh group, which was involved in the US Binary Black Hole Grand Challenge program. After two years in the US, Husa was offered a five-year junior scientist position at the Albert Einstein Institute (AEI) in Potsdam, Germany, to take over the numerical relativity activities at its mathematical relativity division. After five years he joined a new group at the University of Jena as a postdoc, to switch to astrophysically motivated work on the yet unsolved binary black hole problem. A few months before the move, a surprising first stable numerical evolution of a

Sascha Husa.
Credits: Sascha Husa.

black hole merger at CalTech had ended four decades of unstable codes, and in Jena, Husa worked on a number of pioneering papers that defined the state of the art in numerical relativity. He obtained the German habilitation in 2006 and was upgraded to a lecturer with a four-year contract. In the same year he initiated a meeting between researchers from Jena University and the competing AEI to explore opportunities to pioneer the interface between numerical relativity and gravitational wave analysis. This gave rise to a programme to construct phenomenological waveform models, which quickly became the basis for new developments in gravitational wave data analysis. In order to be able to join the LIGO collaboration and deepen his involvement with the challenge to discover gravitational waves in 2007, Husa moved to the Astrophysical Relativity division at AEI. There he played a key role in initiating the "Ninja" community project to provide numerical waveforms to data analysts, jump-starting the use of non-perturbative waveforms in gravitational wave data analysis.

A year later he was finally able to solve the two body problem in physics by taking up an assistant professor position at the University of the Balearic Islands, where Alicia Sintes had previously started a LIGO group. Husa took responsibility for the work on compact binary coalescence, and eventually obtained a permanent position in 2013. As the PI of four European PRACE projects he led an international collaboration to explore the parameter space of black hole coalescences and further developed the phenomenological waveforms program, which constituted the key Spanish scientific contribution to the 2015 discovery of gravitational waves.

After this discovery, the UIB group could grow substantially and maintain its leadership in waveform modelling and data analysis of continuous gravitational waves in an ever more competitive field. Maintaining an internationally competitive effort at a teaching oriented institution became, however, increasingly difficult, especially for a foreigner who had joined the Spanish university system relatively late, and it was clear that new paths had to be sought. In 2023, Sachsa joined ICE-CSIC as Científico Titular.

Daniele Viganò

After having studied in Italy, Daniele Viganò obtained his PhD at the University of Alicante, Spain, in 2013, with an awarded thesis, Magnetic fields in neutron stars. He obtained breakthrough results regarding the evolutionary models of isolated neutron stars, which are considered the state of the art by the community. Then, he moved for the first time to ICE-CSIC for a postdoc, where he dealt with observations in X-ray and theoretical modelling of pulsars' gamma-ray emission. In 2017, he joined the Gravity and Relativity group at the University of Balearic Islands in Mallorca, Spain, where he led the high-performing-computing line of research about small-scale instabilities yielding MHD turbulence in binary neutron star mergers, providing a novel approach based on Large Eddy simulations. Then, in 2019 he returned to ICE-CSIC, to lead the new 3D neutron stars magneto-thermal code development within the ERC Consolidator Grant Magnesia (PI Nanda Rea). In 2021, Daniele obtained an ERC Starting Grant for the IMAGINE project, which is studying magnetic fields on exoplanets and cool stars, and served to create his own group at ICE-CSIC, dealing with magnetic fields in astrophysics from an interdisciplinary point of view. The ERC project studies this topic from both a theoretical point of view (via long-term models and dynamo simulations) and radio interferometry observations with VLA and GMRT. Since 2023, he has been appointed as permanent staff member at ICE-CSIC. He is also actively collaborating

Daniele Viganò.
Credits: Xavier Lapuente/ICE-CSIC.

with the Multimessenger Astrophysics group, the star formation group, the exoplanet group and the Magnesia group at ICE-CSIC.

His work and research expertise are not only related to astrophysics. As a matter of fact, in 2015 he took a break to attend the specialised master "RIDEF 2.0" in Renewable Energies and Energy Efficiency in Milan, Italy. This allowed him to work in the field of international cooperation. First, he worked for CIRPS (Interuniversity Center of Research for Development) in several projects of renewable energies and drinkable water in small rural communities of Central America

and East Africa, as on-site technical assistant for the construction of small power plants. Then, he went on to work in the private sector as a project manager for the EU-funded construction of photovoltaic power plants in Uganda and Eritrea, before going back to astrophysics.

He has extended experience in supervising, teaching and outreach at all levels, for different targets and topics (astrophysics, environment, energy), and study level Primary Education, High School and Master, talks to general or specialised public, seminars and workshops. Within ICE-CSIC, he is the head of the Teaching Committee, and the internal ICE-CSIC coordinator of the Master "High Energy Physics, Astrophysics and Cosmology" of the Autonomous University of Barcelona.

3.3. Guest researchers

During the year, we have received **68** visiting scientists at ICE-CSIC. Most of them (39) stayed for longer than two weeks.

1. **Hernandez Oliu, R.**,Universidad Autónoma de Barcelona, 24/10/2022 - 10/2/2023
2. **Sanfeliu Ruperez, R.**, Universidad Autónoma de Barcelona, 12/12/2022 - 31/7/2023
3. **Menacho Romaña, A.**, Universidad Autónoma de Barcelona, 6/3/2023 - 31/7/2023
4. **Hilario Garcia, A.**, Universidad Autónoma de Barcelona, 14/3/2023 - 30/6/2023
5. **Junyent Dalmau, G.**, Universidad Autónoma de Barcelona, 20/3/2023 - 31/7/2023
6. **Auguets Boixade, Q.**, Universidad Autónoma de Barcelona, 21/3/2023 - 31/7/2023
7. **Rosas Gomez, M. N.**, Universidad Autónoma de Barcelona, 17/4/2023 - 31/7/2023
8. **Garcia Moro, G.**, Universidad Autónoma de Barcelona, 17/5/2023 - 31/7/2023
9. **Anguera Gonzalez, A.**, Universidad Autónoma de Barcelona, 19/9/2023 - 31/7/2023
10. **Pirvu Malanda, R.**, Universidad Autónoma de Barcelona, 5/12/2022 - 30/6/2023
11. **Roxana Birsan, V.**, Universidad Autónoma de Barcelona, 19/12/2022 - 31/8/2023
12. **Gonzalez Bañuelos, M.**, Universidad Autónoma de Barcelona, 2/1/2023 - 30/6/2023
13. **Fernandez Barbat, M.**, Universidad Autónoma de Barcelona, 2/1/2023 - 31/8/2023
14. **Valderrama Flores, I.**, Universidad Autónoma de Barcelona, 16/1/2023 - 30/6/2023
15. **Garrido Moreno, J.**, Universidad Autónoma de Barcelona, 22/2/2023 - 30/6/2023
16. **Perez Piuigvert, X.**, Universidad Autónoma de Barcelona, 6/3/2023 - 30/6/2023
17. **Allande Gonzalez, J.**, Universidad Autónoma de Barcelona, 20/3/2023 - 1/9/2023
18. **Porqueras Leon, O.**, Universidad Autónoma de Barcelona, 27/3/2023- 10/7/2023
19. **Galan Merino, I.**, Universidad Autónoma de Barcelona, 3/4/2023 - 10/7/2023
20. **Valero Triviño, C. L.**, Universidad Autónoma de Barcelona, 26/4/2023 - 30/6/2023
21. **Alcolea Lopez, J. A.**, Universidad Autónoma de Barcelona, 22/6/2023 - 10/9/2023
22. **Azcon Del Viejo, L.**, Universidad de Barcelona, 24/4/2023 - 4/7/2023
23. **Fowler, Z.**, Universidad Internacional de Valencia, 1/12/2022 - 28/2/2023
24. **Kazantsev, C.**, École Normale Supérieure Paris-Saclay, 3/10/2022 - 30/6/2023
25. **Sanchez, C.**, Universidad Autónoma de Barcelona, 1/1/2023 - 31/8/2026
26. **Lehmer, B.**, University of Arkansas, 18/1/2023 - 6/2/2023
27. **Coelho Gomes, N. R.**, Dalhousie University, Faculty of Computer Science, 30/1/2023 - 4/2/2023

28. **Dekarcy, J.**, Virginia Tech, 27/2/2023 - 10/3/2023
29. **Malek, K.**, National Centre for Nuclear Research, 28/2/2023 - 3/3/2023
30. **Pollo, A.**, National Centre for Nuclear Research, 28/2/2023 - 3/3/2023
31. **Elias Rosa, N.**, Astronomical Observatory of Padova, 1/3/2023 - 1/3/2024
32. **Wiseman, P.**, University of Southampton, 20/3/2023 - 24/23/2023
33. **Imbrogno, M.**, National Institute for Astrophysics, 20/3/2023 - 31/3/2023
34. **Lilje, C.**, University of Edinburgh, 18/4/2023 - 19/4/2023
35. **Barrault, L.**, Observatoire de Paris, 3/4/2023 - 14/7/2023
36. **Cross, D.**, Universidad Autónoma de Barcelona, 1/5/2023 - 31/8/2026
37. **Angerhausen, D.**, Eidgenössische Technische Hochschule Zürich, 3/5/2023 - 6/5/2023
38. **Wittje, A.**, University Bochum, 4/5/2023 - 2/6/2023
39. **Konstantinou, A.**, Institute of Astrophysics Forth, 6/5/2023 - 17/5/2023
40. **Ntormousi, E.**, Scuola Normale Superiore di Pisa, 8/5/2023 - 15/5/2023
41. **Damasso, M.**, Observatory of Torino, 8/5/2023 - 12/5/2023
42. **Parimbelli, G.**, Università Degli Studi di Genova, 16/5/2023 - 19/5/2023
43. **Ascenzi, S.**, Gran Sasso Science Institute, 17/5/2023 - 30/7/2023
44. **Abalo Rodriguez, L.**, Leiden University, 21/5/2023 - 25/5/2023
45. **Gonzalez, R.**, Instituto Nacional de Astronomía, Óptica y Electrónica, 26/5/2023 - 15/7/2023
46. **Reboul Salze, A.**, Max Planck Institute for Gravitational Physics, 30/5/2023 - 2/6/2023
47. **Diaz Marquez, E.**, Department of Quantum Physics and Astrophysics, 1/6/2023 - 31/1/2024
48. **Dhawan, S.**, University of Cambridge, 28/6/2023 - 30/6/2023
49. **Ciardi, A.**, Sorbonne Universite, Observatoire de Paris, 28/6/2023 - 31/7/2023
50. **Hamedani Golshan, R.**, Physikalisches Institut University of Cologne, 2/7/2023 - 5/8/2023
51. **Hadasch, D.**, Institute for Cosmic Ray Research, The University of Tokyo, 9/7/2023 - 16/7/2023
52. **Mahani, H.**, Institute for Research in Fundamental Sciences, 13/7/2023 - 21/7/2023
53. **Chatterjee, S.**, Indian Institute of Science Education and Research Bhopal, 17/7/2023 - 21/7/2023
54. **Humina, C.**, University of Turku, 24/7/2023 - 28/7/2023
55. **Rikala, M.**, University of Turku, 24/7/2023 - 28/7/2023
56. **Renard Guiral, P.**, Department of Astronomy, 24/7/2023 - 28/7/2023
57. **Mahdizadeh, S.**, Physikalisches Institut University of Cologne, 7/8/2023 - 19/8/2023
58. **Montesinos Llacer, V.**, Instituto de Fisica Corpuscular, 6/11/2023 - 11/11/2023
59. **Colom Bernadich, M.**, Institut für Radioastronomie, 23/10/2023 - 27/10/2023
60. **Mate, S.**, The Institute of Fundamental Research, 18/10/2023 - 20/10/2023
61. **Cortes, P.**, 18/9/2023 - 18/10/2023
62. **Marretta, A.**, Università Degli Studi di Palermo, 2/10/2023 - 1/3/2024
63. **Duplancic, M. F.**, Videla Conicet, 22/10/2023 - 23/12/2023
64. **Morandi, P.**, Alma Mater Studiorum Universita di Bologna, 18/9/2023 - 17/12/2023
65. **Qiu, Z.**, Keio University Research and Education Center for Natural Science, 27/11/2023 - 5/12/2023
66. **Imbrogno, M.**, National Institute for Astrophysics, 26/11/2023 - 9/12/2023
67. **Trejo Cruz, A.**, Instituto de Radioastronomia y Astrofisica, 13/11/2023 - 24/11/2023
68. **Ascenzi, S.**, Gran Sasso Science Institute, 4/12/2023 - 22/12/2023

4. Research Highlights

4.1. Supermassive black holes found in distant dwarf galaxies

An international team discovered supermassive black holes in dwarf galaxies when the Universe was much younger than it is today, 6,000 million years after the Big Bang. This is a very unusual finding since until now very few cases have been discovered in the local Universe – the Universe today (13.6 gigayears after the Big Bang).

Artist's illustration of a supermassive black hole at the centre of a galaxy.
Credits: NASA/JPL-Caltech.

Supermassive black holes have masses of more than 1 million suns. Every massive galaxy is believed to contain a supermassive black hole at its centre. For example, the one at the centre of the Milky Way is called Sagittarius A and has a mass equivalent to about 4 million suns. Smaller, less massive dwarf galaxies should contain intermediate-mass black holes, smaller than 1 million suns. For a couple of decades, hundreds of intermediate-mass black holes have been located in dwarf galaxies of the local universe thanks to their active galactic nucleus (AGN), since the matter around black holes emits radiation when these are active.

This study presents a sample of seven dwarf galaxies more distant than in most cases, between 10 and 6 billion years after the Big Bang. What has surprised the team is that their mass is consistent with the mass of supermassive black holes, since they are 10 million and 100 million times the mass of the Sun.

Massive galaxies and their super-strong black holes are believed to grow at the same time, they coevolve. For this reason, the findings of this study suggest that black holes have grown faster than their host galaxies. The research team hypothesised that, over time, these galaxies will grow until their mass matches the one of the black hole they host.

Furthermore, the team concludes that these black holes may originate from dwarf galaxies with intermediate-mass black holes in the early universe, 1 billion years after the Big Bang. Researchers have come to this conclusion after running simulations of intermediate-mass black holes or seed black holes (from which supermassive black holes are supposed to grow) and discovering that possibly some of those intermediate-mass black holes have rapidly evolved to become supermassive, unlike their host galaxies.

This finding has implications for our understanding of the growth of supermassive black holes, such as the black hole at the centre of the Milky Way.

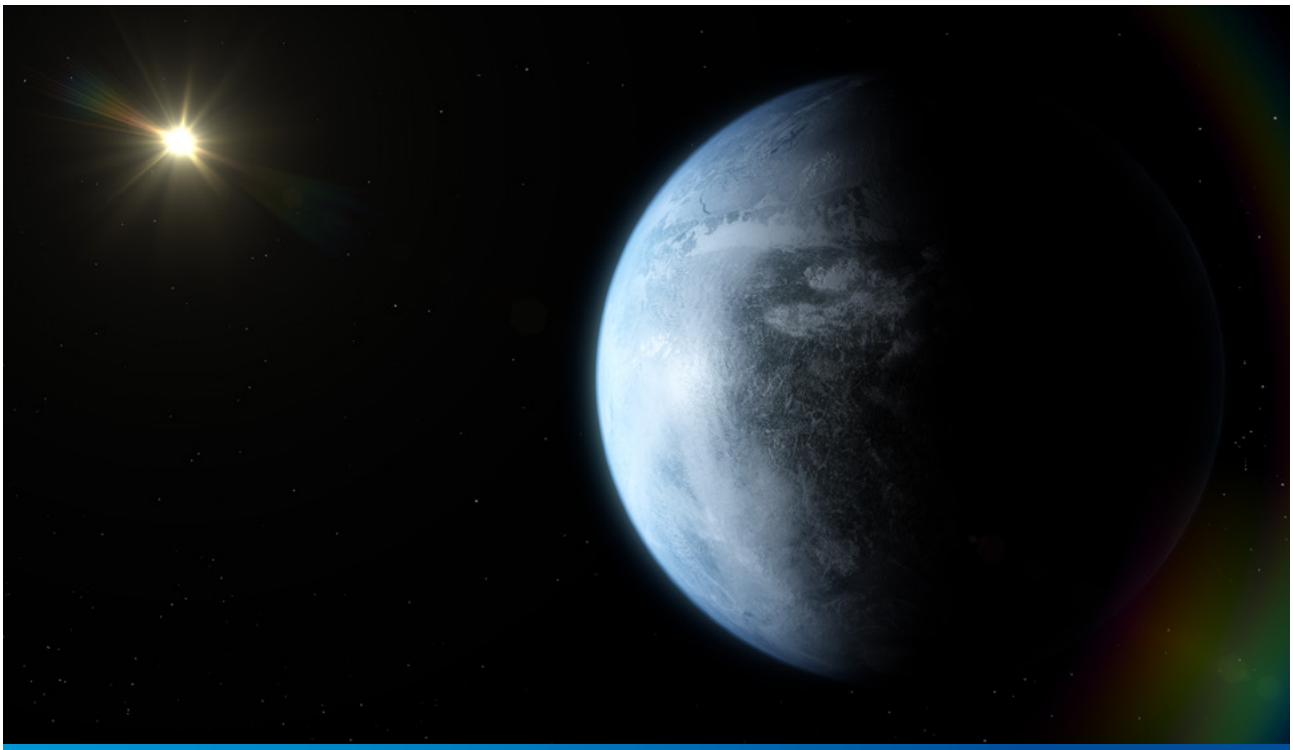
With the new generation of telescopes, such as DESI or LSST, it is expected that many more dwarf galaxies even more distant will be detected, which will allow further investigation of the evolution of black holes from the first seeds to supermassive black holes.

Published in Mezcua et al., incl. Siudek, M. (2023), Overmassive Black Holes in Dwarf Galaxies Out to z ~ 0.9 in the VIPERS Survey, The Astrophysical Journal, 943, L5, 10.3847/2041-8213/acae25.

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

4.2. CARMENES project boosts the number of known planets in the solar neighbourhood

The CARMENES project published data from about 20,000 observations taken between 2016 and 2020 for a sample of 362 nearby cool stars. The project, financed by Spanish and German funds, uses an instrument at Calar Alto Observatory with the purpose of finding Earth-like exoplanets (rocky and temperate), with the possibility of harbouring liquid water on their surface if they are located in the so-called "habitable zone" of their star. Notable among the multitude of released data measurements are those that have led to the discovery of 59 exoplanets, a dozen of which are potentially habitable.



High-resolution image of an Earth-size planet in the cool side of the habitable zone of a nearby M dwarf.
Credits: José A. Caballero, Javier Bollaín (Render Area).

In fact, this instrument has boosted the number of exoplanets we know about around nearby cool stars by doubling those detected with the previously described method. It is to be hoped that, with the publication of this first large dataset, the research community will analyse it and will be able to further increase its scientific output. Importantly, CARMENES has observed almost half of all nearby small stars (part of them can only be observed from the Southern Hemisphere). In addition, the spectra obtained also provide extremely valuable information about the atmospheres of the stars and their planets, among other science cases.

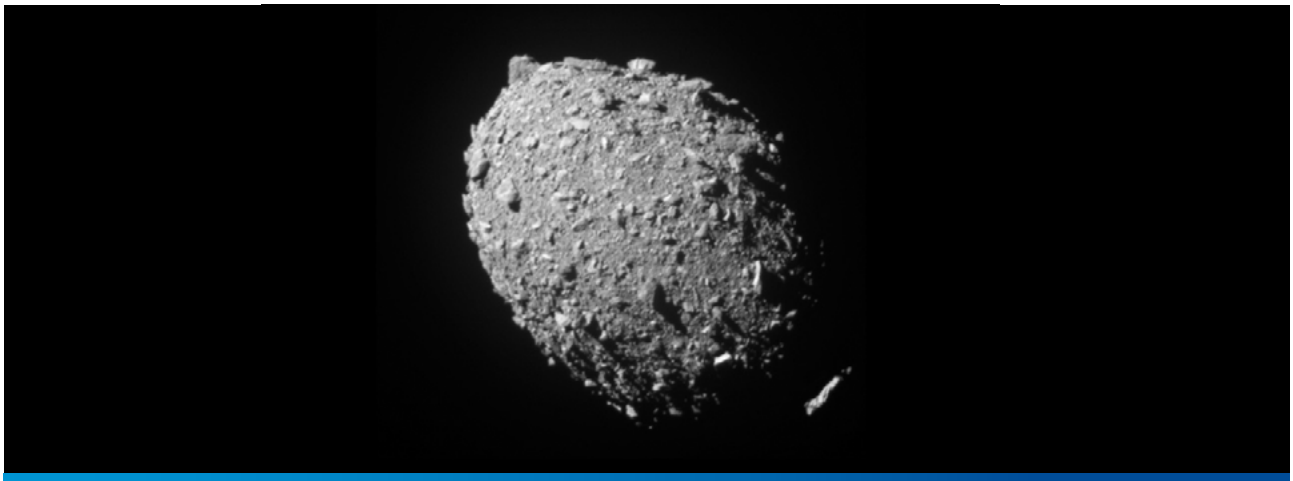
The CARMENES project continues in CARMENES Legacy-Plus, which started in 2021 and keeps taking more observations of the same stars. The observations made in this project extension will continue at least until the end of 2023.

Published in Ribas et al. (2023), The CARMENES search for exoplanets around M dwarfs. Guaranteed time observations Data Release 1 (2016-2020), Astronomy and Astrophysics, 670, A139, 10.1051/0004-6361/202244879.

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

4.3. More than 5 million kilograms of material released after the DART probe collision with Dimorphos asteroid

On 27 September 2022, NASA's DART (Double Asteroid Redirection Test) mission collided with its target, the asteroid Dimorphos, changing its orbit. This was the first planetary defence test mission designed to alter the course of an asteroid. Its success was followed by an intensive analysis of the collision, which includes the study of the tons of asteroidal rocks that were displaced and thrown into space.



Asteroid Dimorphos.
Credits: DART / NASA.

The DART mission sought to prove the usefulness of the kinetic impact method to deflect potentially dangerous asteroids without using explosive charges. Its target, located 11 million kilometres from Earth, was the Dimorphos satellite (with a 160-m diameter) that orbits the asteroid Didymos (with a 780-m diameter), forming a binary system. The impact of the probe, which was travelling at about six kilometres per second, deflected Dimorphos' orbit and shortened its orbital period by more than half an hour regarding Didymos, which was a success for the project.

This study presented a fundamentally morphological study of the evolution of this material, which allowed the researchers to determine the complex interaction between the asteroid system and the dust under the action of the solar radiation pressure.

Asteroid activation is a phenomenon that occurs naturally in the Solar System and produces an increase in brightness of the object and the deployment of a tail of dust similar to that of comets. The DART experiment will help characterise active asteroids in which collisions with other asteroids act as a trigger mechanism.

Another important aspect has been the study and interpretation of the Dimorphos images obtained by the Draco camera onboard DART and from the Italian LICIACube probe, as well as the effects produced in the environment of the binary system of some of the largest telescopes on Earth and in space before and after the impact. The specialisation of the ICE-CSIC team in the chondritic meteorites that make up these asteroids has made it possible to improve the interpretation of the processes that occurred in them. The researchers has also contributed to quantifying the impulse factor produced by the DART crash, the so-called beta factor.

Scientists have found that a probe like DART, based on a technique known as a kinetic impactor to deflect asteroids, has great potential to be effective.

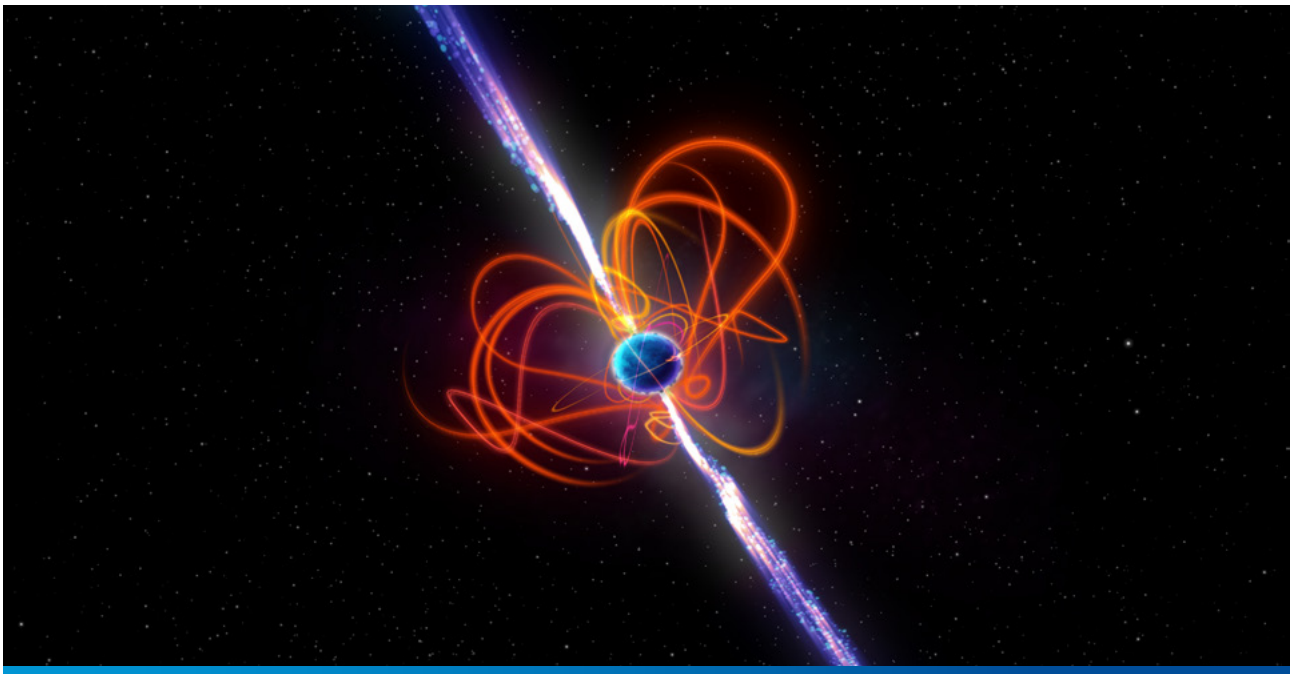
The properties of the crater generated on the surface of Dimorphos, as well as the evolution of the system's dynamics, will be studied by the ESA's Hera mission, which will be launched in 2024 and will begin the study of the system in 2026.

Published in Cheng et al., incl. Trigo-Rodríguez, J. M. (2023), Momentum transfer from the DART mission kinetic impact on asteroid Dimorphos, Nature, 616, 457, 10.1038/s41586-023-05878-z and Li et al., incl. Trigo-Rodríguez, J. M. (2023), Ejecta from the DART-produced active asteroid Dimorphos, Nature, 616, 452, 10.1038/s41586-023-05811-4.

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

4.4. Astronomers discover a new type of stellar object hiding in plain sight

An international team discovered a new type of stellar object that challenges our understanding of the physics of neutron stars. The object could be an ultra-long period magnetar, a rare type of neutron star with extremely strong magnetic fields that can produce powerful bursts of energy, but also a magnetic white dwarf, the old phase of a Sun-like star. None of the current scenarios for those objects can yet successfully explain all the characteristics of this new source. Until recently, magnetars were observed to spin at periods of just a few seconds. The newly discovered object emits radio waves every 21 minutes, and if interpreted as a pulsar it would hold the record for the longest period radio magnetar ever detected.



An artist's impression of the ultra-long period magnetar.
Credits: ICRAR.

The source, named GPM J1839−10, was discovered using the Murchison Widefield Array (MWA), a radio telescope on Wajarri Yamaji Country in outback Western Australia. It is 15,000 light-years away from Earth in the Scutum constellation and it is the second such long periodic radio objects ever detected and observed for the first time at all wavelengths in 2022 by ICE-CSIC researchers.

However, the first discovered long period radio emitter was transient, and stayed bright in the sky for a few months only. This new 21 minutes source is instead observable in archival observations dating back 1988. Follow-up observations of this new object were done with the Gran Telescopio CANARIAS (GTC), along with ESA's XMM-Newton X-ray telescope.

Initially, scientists could not explain what they had found. In January 2022, they published a paper in Nature describing an enigmatic transient object that would intermittently appear and disappear, emitting powerful beams of energy three times per hour. Between July and September 2022, the team scanned the sky using the MWA telescope. They soon found what they were looking for in GPM J1839−10, which emits bursts of energy that last up to five minutes—five times longer than the first object. Other telescopes followed up to confirm the discovery and learn more about the object's unique characteristics. These included three CSIRO radio telescopes in Australia, MeerKAT in South Africa, the XMM-Newton space telescope and the Gran Telescopio Canarias.

Armed with GPM J 1839−10's celestial coordinates and characteristics, the team also began searching the observational archives of the world's premier radio telescopes, popping up in the archives of the Giant Metrewave Radio Telescope (GMRT) in India, and the Very Large Array (VLA) in the USA had observations dating as far back as 1988.

Not all pulsars produce radio waves. Some are believed to lie below the 'death line', a critical threshold where a star's magnetic field becomes too weak to accelerate the particles responsible for the radio waves.

The discovery has important implications for our understanding of the physics of neutron stars and white dwarfs, and the behaviour of magnetic fields in extreme environments. It also raises new questions about the formation and evolution of magnetars and could possibly shed light on the origin of mysterious phenomena such as fast radio bursts.

Published in Hurley-Walker, N., Rea, N., McSweeney, S. J., Meyers, B. W., Lenc, E., Heywood, I., Hyman, S. D., Men, Y. P., Clarke, T. E., Coti Zelati, F., et al. (2023), A long-period radio transient active for three decades, Nature, 619, 487, 10.1038/s41586-023-06202-5.

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

4.5. A stellar corpse shows signs of life through unprecedented flares

An active stellar corpse, caused by a distant star's explosive death, was the likely source of repeated energetic flares observed over several months, a phenomenon never seen before.

Luminous Fast Blue Optical Transient artist's concept.
Credits: NASA, ESA, NSF's NOIRLab, Mark Garlick, Mahdi Zamani.

The bright, brief flashes –as short as a few minutes in duration, and as powerful as the original explosion 100 days later– appeared in the aftermath of a rare type of stellar cataclysm that the researchers had set out to find, known as a luminous fast blue optical transient (LFBOT). It has been officially labelled AT2022tsd and nicknamed "the Tasmanian devil".

Since their discovery in 2018, astronomers have speculated about what might drive such extreme explosions, which are far brighter than the violent ends massive stars typically experience, but fade in days instead of weeks. The research team believes the previously unknown flare activity, which was studied by 15 telescopes around the world, confirms the engine must be a stellar corpse: a black hole or neutron star.

While routinely monitoring the fading explosion in December 2022, the team of researchers found that one of the analysed images picked up light, followed by an intensely bright spike in the middle frame that quickly vanished.

Finding and characterising LFBOTs is challenging due to their nature: they are objects that evolve very quickly. Important information about their explosion mechanisms and physics is lost if we wait a few days to coordinate observations. Therefore, it is important to trigger observations when a good candidate is found. Astronomers have detected around a dozen LFBOTs, of which only six provide some clues about this new class of events. Of these, only one, the so-called 'Tasmanian devil', shows these unprecedented flares.

To further investigate the abrupt rebrightening, the researchers engaged partners who contributed observations from more than a dozen other telescopes, including one equipped with a high-speed camera. The team combed through earlier data and worked to rule out other possible light sources. Their analysis ultimately confirmed at least 14 irregular light pulses over a 120-day period, likely only a fraction of the total number.

Exactly what processes were at work – perhaps a black hole funnelling jets of stellar material outward at close to the speed of light – continues to be studied. The team hopes the research advances long-standing goals to map how stars' properties in life may predict the way they'll die, and the type of corpse they produce.

The unusual explosions promise to provide new insight into stellar life cycles typically only seen in snapshots of different stages – star, explosion, remnants – and not as part of a single system. LFBOTs may present an opportunity to observe a star in the act of transitioning to its afterlife.

Published in Ho et al., incl. Galbany, L., Gutiérrez, C. P., Müller-Bravo, T. E. (2023), Minutes-duration optical flares with supernova luminosities, Nature, 623, 927, 10.1038/s41586-023-06673-6.

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

4.6. Astronomers discover six planets thanks to their synchronised orbits

A team of astronomers found a peculiar family of six planets orbiting a star similar to the Sun called HD 110067. While multi-planet systems are common in our galaxy, those in a tight gravitational formation known as 'resonance' are observed far less often.

The resonant configuration means that the orbits are synchronised in a particular manner. In this case, the planet closest to the star makes three orbits for every two of the next planet out—called a 3/2 resonance—a pattern that is repeated among the four closest planets. For the outermost planets, it is four orbits for every three of the next planet out—a 4/3 resonance. Orbitally resonant systems like this are extremely important to find because they tell astronomers about the formation and subsequent evolution of the planetary system. Planetary systems tend to form in resonance but can be easily perturbed. Finding a resonant system, thus, is like looking at a 'fossil' planetary system.

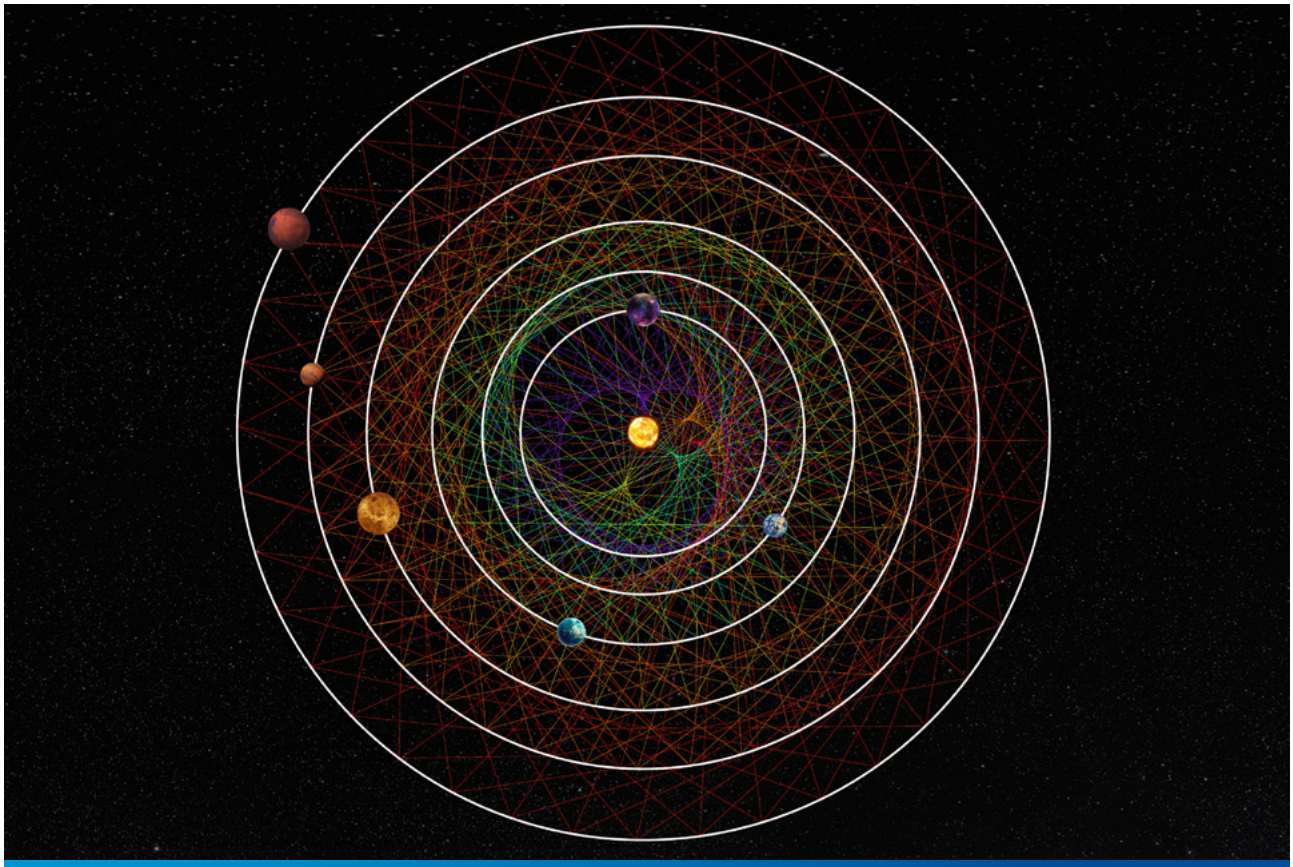
In 2020, TESS satellite detected dips in the brightness of the star HD 110067, which indicated planets were passing in front of its surface. Two years later, TESS re-observed the same star. But it was difficult to distinguish how many planets they represented, or to pin down their orbits; the two sets of observations seemed to disagree.

Eventually, astronomers singled out the two innermost planets, with orbital periods of 9 days for the closest planet and 14 days for the next one out. A third planet, with a year about 20.5 days long, was identified with the help of the data from ESA mission CHEOPS.

The astronomers found that the three planets' orbits matched what would be expected if they were locked in a 3/2 resonance. The science team worked through a well-known list of resonances that potentially could be found in such systems, trying to match them to the remaining transits that had been picked up by TESS. The scientists could therefore predict that the outer three planets have orbital periods of 31, 41 and 55 days.

However, the TESS observations that had any chance of confirming the predicted orbits of the two outer planets had been set aside during processing, as they had excessive scattered light. Reanalysis of the data to correct for the excessive light revealed two hidden transits, one from each of the planets, exactly at the times expected by the predictions.

Furthermore, CARMENES high-resolution spectroscopic observations spanning one year, along with those from the HARPS-N spectrograph, were used to determine the mass of three of the planets



The six planets of the HD110067 system create together a mesmerising geometric pattern due to their resonance-chain.
Credits: Thibaut Roger (NCCR PlanetS).

in the system and set stringent constraints to the others, revealing they are what we call sub-Neptune class planets

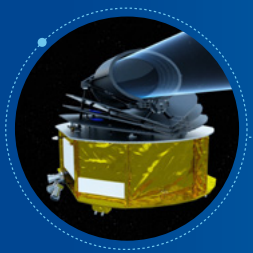
HD 110067 invites further study as it shows us the unaltered configuration of a planetary system that has kept its resonance since its formation: the planets have likely been performing this same gravitational dance since the system formed billions of years ago. Moreover, this is the brightest known system with four or more planets. Since those planets are all sub-Neptune-sized with atmospheres that are likely extended, it makes them ideal candidates for studying the composition of their atmospheres using the James Webb Space Telescope.

Published in Luque et al., incl. Morales, J. C., Anglada-Escudé, G., Ribas, I. (2023), A resonant sextuplet of sub-Neptunes transiting the bright star HD 110067, Nature, 623, 932, 10.1038/s41586-023-06692-3.

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

5. Missions and experiments

ICE-CSIC participates in exciting space 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.


ARIEL


ARRAKIHS


NEWATHENA


CARMENES


CHEOPS


CTAO

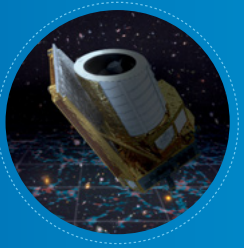

DART


DES


DESI


EINSTEIN PROBE


EINSTEIN TELESCOPE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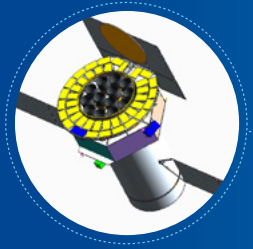
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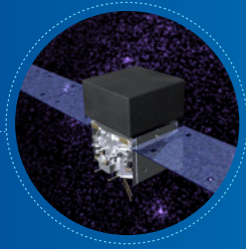
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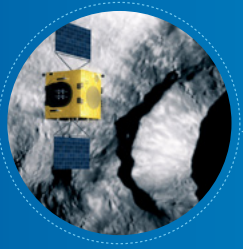
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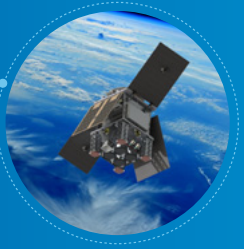
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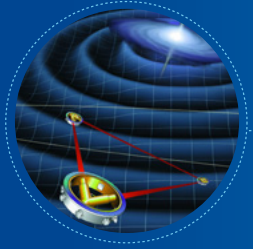

LISA


PAU


PAZ


PLATO


ROMAN


STROBE-X

1 ARIEL

Senior Institute members involved: **I. Ribas, J. Colomé, G. Anglada-Escudé**

Department of Astrophysics and Planetary Sciences

Ariel is an ESA mission, due for launch in 2029, aimed to answer fundamental questions about how planetary systems form and evolve by investigating the atmospheres of several hundred planets orbiting stars other than the Sun.

The Ariel mission concept is developed by a consortium of more than 50 institutes from 16 ESA countries. ICE-CSIC is one of the co-PI institutes (co-PI: Ribas) and leads the Spanish contribution (PI: Ribas; National Project Manager until October 2023: Colomé), which also includes the Instituto de Astrofísica de Canarias and the Universidad Politécnica de Madrid. The groups at CSIC and UB, 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 controls the secondary mirror (M2) refocusing mechanism (M2M) under operation from the ground.

Recent developments

The Ariel mission passed a major milestone in May after successfully completing its Payload Preliminary Design Review. This demonstrates that the mission's payload design meets all the required technical and scientific specifications, and no showstoppers exist for the foreseen launch in 2029. The Ariel consortium payload team prepared 179 technical documents and addressed 364 questions for a panel of ESA experts, in which the ICE-CSIC team actively participated. The review scrutinised every aspect of the proposed payload, to ensure that the designed systems meet the technical, scientific, and operational requirements of the mission. Ariel's payload critical technology is now sufficiently mature for the mission to proceed to payload Critical Design Review and begin to manufacture its first prototype models.

Further work was devoted to the detailed design of the electronics associated with the TCU and we continued with the industrial collaboration to provide the M2M. The latter is performed via a contract between ESA and Sener Aeroespacial as a result of the Spanish Prodex call, with participation from the ICE-CSIC team. The goals are to design, manufacture and qualify the operation of the M2M at cryogenic temperature. Finally, the mission planning algorithms were evolved, developing a graphical interface prototype and running simulations to test its efficiency, while demonstrating the adequacy of the intended sample of objects and the observation strategy for the mission. The formal top-level requirements that the scheduler must fulfil were also defined at the end of this year.

On the science side, the group continued to study the effects of stellar activity on the determination of exoplanetary spectra in the context of the Ariel Stellar Activity Working Group.

2 ARRAKIHS

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

Department of Cosmology and Fundamental Physics

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

2023 has been the first year of the ARRAKIHS mission, where the consortium, science and instrument have been consolidating. From February to March, we spent one month at ESA's Concurrent Design Facility (CDF), reviewing all aspects of the space mission with experts from all areas. Many things were learnt from CDF but the mission became too complex for an F-class type. Phase 0 was extended and after 4 months of intense Post-CDF work, we identified a feasible mission concept that was compatible with ESA's Fast Mission boundary conditions.

On 27 September, the ARRAKIHS team successfully passed the Mission Definition Review, concluding the activity of phase 0. Then, the mission entered a very short phase A of four months, that will end with the Preliminary Requirements Review in February 2024.

ICE-CSIC/IEEC organised the first ARRAKIHS Mission Consortium in July 2023, where our Institute welcomed 40 scientists and engineers. A national research plan was granted and started in September, with Pablo Fosalba (IEEC project PI) and Santiago Serrano (ARRAKIHS Instrument PI), with additional participation in various science groups from Francisco Castander and Enrique Gaztañaga. Additionally, a Prodex project currently ongoing where the Institute is elaborating a feasibility study for the instrument Fine Guidance System.

ARRAKIHS Consortium members meeting reviewing all aspects of the space mission with experts from all areas at ESA's Concurrent Design Facility in February 2023.
Credits: ESA.

3 NewAthena

Senior Institute member involved: **N. Rea**

Department of Astrophysics and Planetary Sciences

The NewAthena mission will be the next generation large X-ray observatory offering partially-resolved X-ray spectroscopy and deep wide-field X-ray spectral imaging with performance greatly exceeding that offered by current X-ray observatories. It was selected in 2014 by ESA to become the second L-class mission of its Cosmic Vision programme. This huge X-ray observatory will first, determine how and when large-scale structures formed in the Universe and track their evolution from the formation epoch to the present day; second, perform a complete census of black hole growth in the Universe, determine the physical processes responsible for that growth and its influence on larger scales, and trace these and other energetic and transient phenomena to the earliest cosmic epochs; and third, provide a unique contribution to astrophysics in the 2030s by exploring high energy phenomena in all astrophysical contexts, including those yet to be discovered.

ICE-CSIC hosts a member of the ESA NewAthena Science Redefinition Team (SRDT), who was previously part of the ESA Athena Science Study Team. The NewAthena SRDT was selected via an open competition by ESA to provide scientific oversight of the instrument redesign that happened in the period 2022-2023. During summer 2022, due to an excess of the estimated mission costs at completion, ESA defined the NewAthena SRDT to help the re-design and re-formulation of the mission under an established cost-cap. The main responsibilities of this team

were in the fields associated with the scientific themes, review and propose updates to the mission scientific requirements and assess the scientific aspects of the mission performance under this new mission design.

Recent developments

The redefinition activities were successfully completed in late 2023, discussed by the ESA Science Programme Committee that allowed NewAthena to re-enter on track with the industrial development, with the next key milestone being the final mission adoption expected in early 2027, leading to launch in 2037.

Group picture of the NewAthena Science case: SRDT/TPCs meeting held at ICE-CSIC on 28-29 June 2023.
Credits: ICE-CSIC.

4 CARMENES

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

Department of Astrophysics and Planetary Sciences

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 the 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.

Recent developments

The CARMENES survey has been ongoing since 2016. The official Guaranteed-Time Observations finalised at the end of 2020 (750 nights) and since then the observations are being performed within the CARMENES Legacy-Plus project (Ribas as co-PI). An extension request for the project was successfully granted in 2023, which will ensure its continuity until at least the end of 2026 (650+ nights). The ICE-CSIC team is in charge of coordinating the acquisition of data on the sample of ~350 M-dwarfs, monitoring instrument performance, organising possible candidate follow-up and supervising the announcement of new planet discoveries.

In 2023, CARMENES has published 20 new papers (including those 'in press'), with some very relevant results, such as the discovery of 8 new planets (4 of them having masses compatible with terrestrial properties and temperate surface conditions) and the confirmation and measure of 7 additional planets from the follow-up of TESS transiting candidates. A major outcome of the survey in 2023 was the release of about 20,000 observations taken between 2016 and 2020 for a sample of 362 nearby cool stars (Ribas et al. 2023). Notable among the multitude of released data measurements are those that led to the discovery of 59 exoplanets, a dozen of which are potentially habitable. The paper, published in Astronomy & Astrophysics, is the 100th article of the CARMENES Consortium, which shows how successful the project has been in providing information about Earth-like exoplanets and their stars.

5 Cheops

Senior Institute members involved: **I. Ribas, G. Anglada-Escudé**

Department of Astrophysics and Planetary Sciences

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 mission was launched in December 2019 and it has been on nominal operations since April 2020.

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 2023, Cheops produced a large number of publications, totalling 26, which include several highlights where our Institute is involved. Examples are the observation of the phase curve and occultation of the ultra-hot planet 55 Cnc e (Demory et al. 2023; Meier Valdes et al. 2023) and the detailed exploration of warm mini-Neptunes (Ulmer-Moll et al. 2023; Tuson et al. 2023; Osborn et al. 2023; Garai et al. 2023). But the most relevant result was the announcement of a resonant sextuplet of planets. This remarkable system was uncovered by analysing transit events reported by the TESS mission and applying orbital dynamics to predict future precise transit timings of the full system of 6 planets. Such transit events were subsequently observed and measured with Cheops. The publication appeared in the journal Nature (Luque et al. 2023) and received plenty of worldwide media attention.

6 CTAO

Senior Institute member involved: **D. F. Torres**

Department of Astrophysics and Planetary Sciences

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 from 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, our Institute is leading a number of the 'Key Science Programs' (KSPs) putting an effort on maximising the physic output of the observatory. This follows our earlier efforts: Prof. Torres has been the global Science Coordinator of the whole collaboration for 8 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, Dr. Emma de Oña, another ICE-CSIC member occupied this post for another year.

Recent developments

On September and October 2023, the Array Control and Data Acquisition (ACADA) team, alongside the Large-Sized Telescope (LST) Collaboration, reached a milestone: we were able to successfully integrate and test the first release of the ACADA software with the LST-1, the LST prototype in La Palma, Spain. ACADA will be the central software in charge of operating the CTAO's two arrays of telescopes and other instruments, so these first tests were fundamental in assessing the software's functionality on an individual telescope before extending its application to a wider scope. This is the culmination of almost two years of preparation. More than 60 members of the ACADA team from nine countries participated, with the ICE-CSIC CTAO leading the integration of the CTAO scheduler.

7 DART

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

Department of Astrophysics and Planetary Sciences

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

As part of the DART Investigation Team, ICE-CSIC has promoted state-of-the-art experiments and techniques to infer the mechanical properties of the chondritic materials that form the Didymos system, used to evaluate the effectiveness of this mitigation approach. In addition, we share our know-how about the main processes affecting the reflectivity, and surface properties of chondritic asteroids. We have also contributed to the study of the evolution of the DART's impact plume using ground-based modern telescopes. We participated in the photometric monitoring of DART's impact effects. We are studying the dynamics of the particles released by DART impact, and infer their evolution into separate orbits, once detached from Dimorphos.

Illustration depicting NASA's DART spacecraft prior to impact at the Didymos binary asteroid system.
Credit: NASA/Johns Hopkins APL/Steve Gribben.

8 DES

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

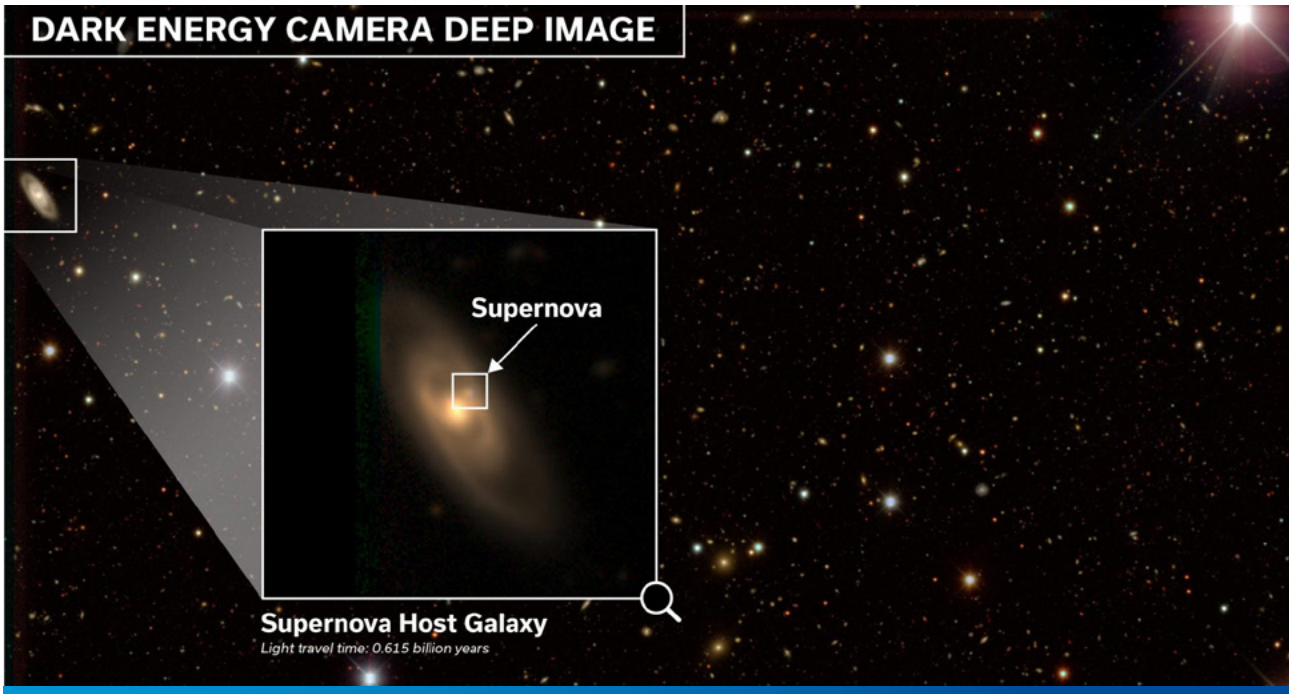
Department of Cosmology and Fundamental Physics

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), SNIa and Clusters. These articles are expected to be submitted throughout 2024, leading to legacy results.

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. Very recently the Supernovae group completed an analysis to constrain the expansion rate of the Universe using 1500 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, were very recently submitted (is publicly available here) with huge media impact, e.g. dozens of news articles, including many international (Argentina, India, Italy, Columbia, France, UK, Germany, etc.) and a number of fairly high profile interviews (e.g. BBC, Chicago CBS, etc.). See for instance this article. In turn the BAO analysis was also finalised incorporating 50% more galaxies improving constraining power on the distance to redshift of about 1 by 25% with respect to the Y3 analysis. These articles are currently in internal Collaboration Wide Review and will be submitted in February 2024.

Lastly the flagship shear and clustering analysis is also incorporating over 20-30% more galaxies, and better control of systematics, thanks to the higher depth of DESY6 data. Cosmological constraints from the combination of galaxy clustering and lensing is expected by late 2024. The cosmology group at ICE-CSIC in collaboration with the Spanish Excellent Network (SPADES) is leading and contributing to different parts of this comprehensive and exciting analysis.



An example of a supernova discovered by the Dark Energy Survey within the field covered by one of the individual detectors in the Dark Energy Camera. The supernova exploded in a spiral galaxy with redshift = 0.04528, which corresponds to a light-travel time of about 0.6 billion years. This is one of the nearest supernovae in the sample. In the inset, the supernova is a small dot at the upper-right of the bright galaxy centre. Credits: DES collaboration.

9 DESI

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

Department of Cosmology and Fundamental Physics

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 and redshift space distortions. ICE-CSIC, together with IFAE, has built the guiding and focusing 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 2023, DESI completed its second year of observations. Operations have continued routinely. The Kitt Peak observatory had an incident of cyber security and cut off all its connections to the outside world. All DESI communications were disrupted, but now there are new more secure protocols for the observatory and the survey. The Mayall telescope was re-aluminised during the summer shutdown and the transmission has improved since. DESI has now gathered around 27 million spectra of galaxies and quasars and around 10 million spectra of stars. Given the programme being ahead of schedule, the bright programme was extended with two more passes. This autumn DESI passed its 50% mark, now being more than half complete. The data for the Data Release 1 was internally provided to the DESI collaboration blinded for cosmological analysis. Two workshops at the end of the year were held to prepare for the unblinding.

In 2023 there were two collaboration meetings that took place in Durham, UK, in July and Hawaii, USA, in December. In December as well, the Report of the Particle Physics Project Prioritization Panel (P5 Report) was delivered with very good prospects for the continuation of DESI into DESI-II and a future more ambitious spectroscopic programme.

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 being nominated coordinator of the Galaxy and Quasars Science Working Group. In terms of science developments, we have continued with our involvement in the galaxy clustering, galaxies and quasars and C3 science working groups; and participated in some secondary programmes.

10 Einstein Probe

Senior Institute members involved: **N. Rea**

Department of Astrophysics and Planetary Sciences

The Einstein Probe is an X-ray astronomical space mission led by the Chinese Academy of Sciences in collaboration with the European Space Agency (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.

Einstein Probe was launched on 9 January 2024 and 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

In 2023 the group at ICE-CSIC involved in Einstein Probe prepared the scientific activity for the launch in 2024. In particular, as the Chair of the Science Topical panel on Compact Objects topical we organised the writing of the relative section of a White Book with detailed simulations and estimates for the mission. This work will be published soon after the launch in 2024.

11 Einstein Telescope

Senior Institute members involved: **C. Sopuerta, M. Mezcua**

Department of Cosmology and Fundamental Physics

The Einstein Telescope (ET) is a proposed underground infrastructure to host a third-generation, gravitational-wave observatory. It builds on the success of the current, second-generation laser-interferometric detectors Advanced Virgo and Advanced LIGO. 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. With a successful European Strategy Forum on Research Infrastructures (ESFRI) proposal, the project will enter its preparatory phase, which foresees the beginning of construction in 2026 with the goal to start observations in 2035.

ICE-CSIC researcher Carlos F. Sopuerta is the leader of a 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 32 ET collaboration members. ICE-CSIC is the one that contributes more scientists to this collaboration, with a total of 17 members, covering a very wide range of topics of interest for third-generation ground-based gravitational wave detectors, like the ET.

Recent developments

Among the main activities in 2023, it is worth mentioning that there has been an exhaustive study of different possible configurations for the Einstein Telescope whose merit has been evaluated in terms of the science return. This study will be key for deciding the site and features of the Einstein Telescope. During 2023, the ET-CSIC RU has consolidated and started to define objectives for the next years.

12 EUCLID

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

Department of Cosmology and Fundamental Physics

Euclid is an ESA cosmology mission to map the geometry of the Universe and better understand the mysterious dark matter and 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.

Euclid's first images. Top (from left to right): spiral galaxy IC 342, Horsehead Nebula and Globular cluster NGC 6397. Bottom (from left to right): Irregular galaxy NGC 6822 and Perseus cluster of galaxies.

Credits: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi.

Recent developments

During the first part of 2023 Euclid passed its last test on ground and was shipped in April to Cape Canaveral, Florida, USA. Two weeks prior to launch, the Euclid Consortium held its annual meeting in Copenhagen, Denmark. On 1 July 2023, Euclid was successfully launched with the Falcon9 rocket from SpaceX. The launch was very efficient and Euclid was injected into its orbit without the need for major manoeuvre corrections. In a month, Euclid reached its target orbit around the Lagrange L2 point. In the first month, Euclid underwent commissioning making sure that the instruments were functional and adjusting the telescope focus. At the end of July, Euclid released a few demonstration images taken during commissioning to showcase the potential of Euclid. In August, Euclid started its Performance Verification (PV) phase. In mid August, it returned to commissioning to solve some problems found with the Fine Guide Sensor determination of the telescope guiding. At the end of September the PV phase was re-started, acquiring the data needed to calibrate the mission. In November, Euclid released to the world the Early Release Observations (EROs) of special observations taken during the PV phase. These EROs included observations from galaxy clusters to gaseous nebulae demonstrating the capabilities of Euclid to cover a large field with exquisite image resolution. On 3 December, the Euclid survey officially started taking data. The first observations were made to measure the Wide Front Error and calibrate the system PSF.

ICE-CSIC continued leading the Cosmological Simulations working Group and the Simulations Organisation Unit of the Science Ground Segment. We have been working on improvements to the Flagship simulation and in the writing of the paper describing the mock galaxy catalogue. Together with the Port d'Informació Científica (PIC), we have produced the simulations used in cycles 16 and 19 of the Science Ground Segment and all the simulations required to prepare and support the PV phase of the mission. The paper describing the Science Challenge 8 simulations has been submitted for publication.

13 eXTP

Senior Institute members involved: **M. Hernanz, N. Rea, L. Tolós, D. F. Torres, A. Patruno**

Department of Astrophysics and Planetary Sciences

The enhanced X-ray Timing and Polarimetry Mission (eXTP) is an X-ray satellite planned by China and Europe, expected to be launched in 2029. It will include four instruments, two led by China (IHEP/CAS, Institute of High Energy Physics from the Chinese Academy of Sciences) and two by Europe. The PI of the Wide Field Monitor (WFM) is Margarita Hernanz, research professor from ICE-CSIC and IEEC. The LAD (Large Area Detector), SFA (Spectral Focusing Array) and PFA (Polarimetry Focusing Array), are the three other eXTP instruments, with the LAD led by Italy and the SFA and PFA by China.

ICE-CSIC/IEEC eXTP group's contribution is the whole mechanical structure of the WFM cameras, their interfaces (thermal, mechanical, electrical, data) with the eXTP platform, as well as their assembly, integration and tests before sending them to the prime contractor of the satellite in China (IAMC - Microsat, Shanghai).

Recent developments

The WFM and the LAD (eXTP's two European payloads) successfully passed their System Requirements Review in 2023: data package delivery and kick-off meeting took place in February 2023, Request about Item Discrepancies from the panel (with ESA, Italy and Spain participation) were received in March and answered in April. The final review meeting took place also in April 2023 in Rome, Italy.

At the end of February and the beginning of March 2023, we hosted the visit to ICE-CSIC of a high-level delegation from China, including the PI of eXTP and other CAS representatives from IHEP and the National Space Science Centre (NSSC) to discuss the current status of the project. That same Chinese delegation and M. Hernanz met the ESA Space Programme Committee Spanish Delegates in Madrid.

Visits and face-to-face meetings of our group with eXTP Chinese colleagues in Shanghai (Microsat) and Beijing (IHEP and NSSC) took place in May 2023.

Progress in the design and development of prototypes (Demonstration Models), needed to finish Phase B in 2024, has been made with the collaboration of industries like Sener Aeroespacial and Tecnalia from Spain and Azimut Space from Germany.

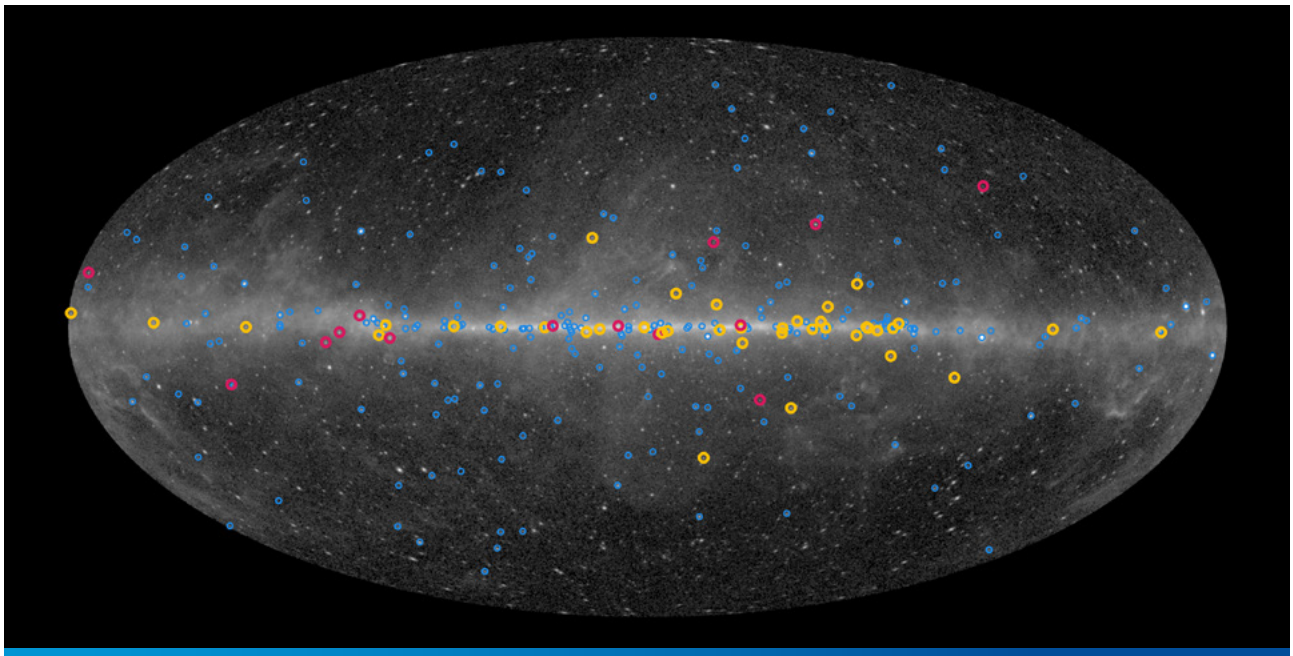
14 Fermi

Senior Institute member involved: **D. F. Torres**

Department of Astrophysics and Planetary Sciences

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.

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 Catalog, or the spectral pipeline of the Second Fermi-LAT Pulsar Catalog.



The entire sky as seen by NASA's Fermi Gamma-ray Space Telescope. The plane of the Milky Way runs along the horizontal line in the middle. The grey scale shows the intensity of the observed gamma radiation. Small blue circles mark the pulsars in the now published catalogue. Yellow and red circles show the 53 gamma-ray pulsars discovered by scientists at the Max Planck Institute for Gravitational Physics in Hannover. The yellow circles mark the gamma-ray pulsars discovered by the Einstein@Home distributed computing project, and red circles the gamma-ray pulsars found with the Atlas computer cluster.

Credits: The Fermi-LAT collaboration/MPI for Gravitational Physics.

Recent developments

The Large Area Telescope Collaboration released the third catalogue of gamma-ray pulsars (3PC) using as much as 14 years of data. The catalogue reports 340 gamma-ray pulsars and candidates, including 294 gamma-ray pulsars found in the LAT data; 33 millisecond pulsars (MSPs) discovered in deep radio searches of LAT sources; and a dozen optical and/or X-ray binary systems co-located with LAT sources that likely harbour gamma-ray MSPs. The electronic catalogue version provides gamma-ray pulsar

ephemerides, properties and fit results to guide and be compared with modelling results. An all-sky gamma-ray sensitivity map is provided for population synthesis studies. Photon data files are provided for the gamma-ray pulsars that include phase and model weights. The 3PC Catalogue data products are available online, where you can find individual summary pages for the gamma-ray pulsars. The construction and details of the catalogue are described in the 3PC paper. This is an impressive achievement that was years in the making, and that will be profusely used in pulsar research, with different members of the ICE-CSIC Multimessenger group in Fermi participating all along the process.

15 Hera

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

Department of Astrophysics and Planetary Sciences

Hera is an ESA mission that will visit the binary asteroid Didymos to map Didymos and Dimorphos at high resolution at the same time 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. Hera is expected to be launched in 2024 and reach Didymos binary system in December 2026.

Recent developments

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.

Dr. 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.

16 HydroGNSS

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

Department of Astrophysics and Planetary Sciences

HydroGNSS is the second ESA's Scout mission[2]. 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, for the launch planned in 2024. During 2023, the Earth Observation Group has developed and implemented the final versions 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, the exploitation of which is responsibility of the researchers at ICE-CSIC. All these algorithms and processors are part of the operational Payload Data Ground Segment of the mission.

[2] ESA Scout missions, which are a new element in ESA's Earth Observation FutureEO Programme, aim to demonstrate how small satellites on a budget of less than €30m and a three-year schedule can play an important role in Earth Observation, and be scaled up for future missions.

17 LISA

Senior Institute members involved: **C. Sopuerta, M. Nofrarias**

Department of Cosmology and Fundamental Physics

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 contribution to LISA is the Data and Diagnostics Subsystem. The Data subsystem 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, that will provide essential information about the environment of the LISA measurement system.

Recent developments

The year 2023 has been crucial as we have supported the LISA mission through the adoption mission review process, whose result is supposed to become official at the beginning of 2024. From the instrumental part, we lead the Spanish contribution to the mission, consisting of the Science Diagnostics Subsystem (Miquel Nofrarias is the PI leading this effort), and as a consequence we have done the work for this subsystem to go through adoption, including tests and reports. Moreover, during 2023, we have successfully concluded the LISA Enhanced Temperature Subsystem (LETS) activity. LETS was an ESA contract to develop a prototype for the temperature diagnostics subsystem for LISA, which has been already manufactured and tested. This prototype, currently in use at ICE-CSIC labs, achieves high precision performances in temperature sensing (~microkelvin resolution), and will be used for the forthcoming phases of LISA implementation and testing.

On the science exploitation side (Carlos F. Sopuerta is the PI leading this effort), we are also going to lead the Spanish contribution in the form of a Data Distributed Center together with a so-called global fit pipeline which will create a catalogue of gravitational sources from the LISA Data stream. On the other hand, Carlos F. Sopuerta, as member of the ESA LISA Science Study Team, has been supporting ESA in the adoption process, in particular by being one of the leading authors of the LISA Definition Study Report (the so-called Red Book), which will be made public during 2024. Finally, Miquel Nofrarias and Carlos F. Sopuerta have supported the Spanish delegation in the definition of the multilateral agreement for LISA, where the Spanish contribution is defined.

ICE-CSIC engineer Ana Pérez discussing with ICE-CSIC Faculty Miquel Nofrarias while working on the lab in the framework of ESA´s LISA mission.

Credits: César Hernández.

18 PAU

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

Department of Cosmology and Fundamental Physics

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. Our Institute is leading the Science and operation of the PAU Survey. We also manage the international collaboration and data reduction.

Recent developments

During 2023 we continued to focus our efforts on the science analysis of the PAU Wide fields. These are three regions (which we called W1, W2 and W3 together with the COSMOS and W4 calibration fields) with 2 million galaxies over 50deg^2 area (with 30 to 40 narrow bands and 3 exposures each) and have deep weak lensing information. During 2023, we have measured high quality photometric redshifts using two different methods (template and machine learning based) to do weak gravitational lensing and clustering analysis, to detect the intrinsic clustering and intrinsic alignment signal of galaxy shapes. This is an important contaminant for current (e.g. DES and KIDS) and future (Euclid and LSST) cosmological analysis.

We have also completed and submitted papers on: the PAUS calibration paper, galaxy formation, SED classification, closed galaxy pairs and a joint paper with Euclid to use PAUS data to obtain better broadband photometric redshift: Navarro-Gironés et al. (2023); Manzoni et al. (2023); González-Morán et al. (2023); Gonzalez et al. (2023), and Cabayol et al. (2023).

19 PAZ

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

Department of Astrophysics and Planetary Sciences

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 occultations 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 hypothesis of the experiment: 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 improving the modelling/forecast/climate projections of these extreme events. The polarimetric data are accessible through the ROHP-PAZ website, 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 JPL, the experiment is possible through collaborations with the PAZ satellite owner, operator and exploiter, Hisdesat, the National Oceanic and Atmospheric Administration (NOAA) and the University Corporation for Atmospheric Research (UCAR). 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 2023, 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. Since January 2023, these data sets were the only GPS signals acquired at two polarisations from a spaceborne satellite. Three more low Earth orbiters are equipped with GNSS PRO payloads, as part of the Spire Global commercial constellation. ICE-CSIC has participated in the independent validation of these commercial

GNSS PRO data, through an ESA project. We have also co-organised, together with NASA/JPL, the 2nd PAZ-Polarimetric Radio Occultations User Workshop on 28-29 November 2023 at the Keck Institute in Caltech, Pasadena CA, USA. Around 80 people registered for this hybrid event, with 28 participants in-person. Participants from 14 countries, 3 continents and over 40 different affiliations discussed the new applications and challenges of this technique.

20 PLATO

Senior Institute members involved: **I. Ribas, J. Colomé, A. Serenelli**

Department of Astrophysics and Planetary Sciences

The PLAnetary Transits and Oscillations of stars (Plato) is the selected M3 mission in ESA's Cosmic Vision programme, to be launched in 2026. Its objective is to find and study a large number of extrasolar planetary systems, with emphasis on the properties of terrestrial planets in the habitable zone around solar-like stars. Plato has also been designed to investigate seismic activity in stars, enabling the precise characterisation of the planet host star, including its age.

A major task of ICE-CSIC's contribution to Plato, in collaboration with a broader IEEC team, is to distribute and optimise the observations of the ground-based follow-up using the proven expertise in sophisticated scheduling algorithms. The exoplanet candidates received from the Plato Data Center will be distributed among the different facilities according to the relevant parameters and to the availability of observing time. Furthermore, ICE-CSIC is also responsible for the production of the libraries of stellar models required to determine stellar fundamental parameters.

Recent developments

During 2023, the team of the Ground-based Observation Programme (GOP) has been redefining its structure and responsibilities. As a result of the last agreements, the group assumed the responsibility of developing the communications and data handling system as well as the optimisation and scheduling tools of the GOP. During 2023 we contributed to the first version of the Requirements and Design document of the system that was internally reviewed and Request about Item Discrepancies were raised. This activity is key to the success of the Plato mission since the candidate targets will have to be vetted and confirmed through a sequence of observations using a wide variety of facilities. Our role will be to provide the software infrastructure to distribute the targets and observations in an optimal way so that the science results of the mission can be optimised. We have started to develop the Plato-GOP scheduled software using as a test case a catalogue of mock planet candidates, and making use of the libraries developed in the STARS framework. A key point is the interfacing between the scheduling tool and the various facilities that will be registered in the Plato follow-up consortium. Various solutions are being tested, most importantly those based on the Virtual Observatory standard.

In addition, we are helping to better define the science case of the future Plato mission and prepare the data analysis tools. The forward functionality of StarSim is being applied to the Plato simulator (PlatoSim) and we have been contributing to the work packages on Stellar Activity and Rotation and Spot Models.

The group is also 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 program. There will be different generations of libraries with increasing complexity in the physics of stellar models. During 2023, the stellar evolution and stellar oscillation codes to be used to produce the models have been selected, and the calculation of the first-generation library has been started. This library will be included by the Plato Data Centre into the Stellar Astrophysics Pipeline during the first quarter of 2024.

21 ROMAN

Senior Institute member involved: **L. Galbany**

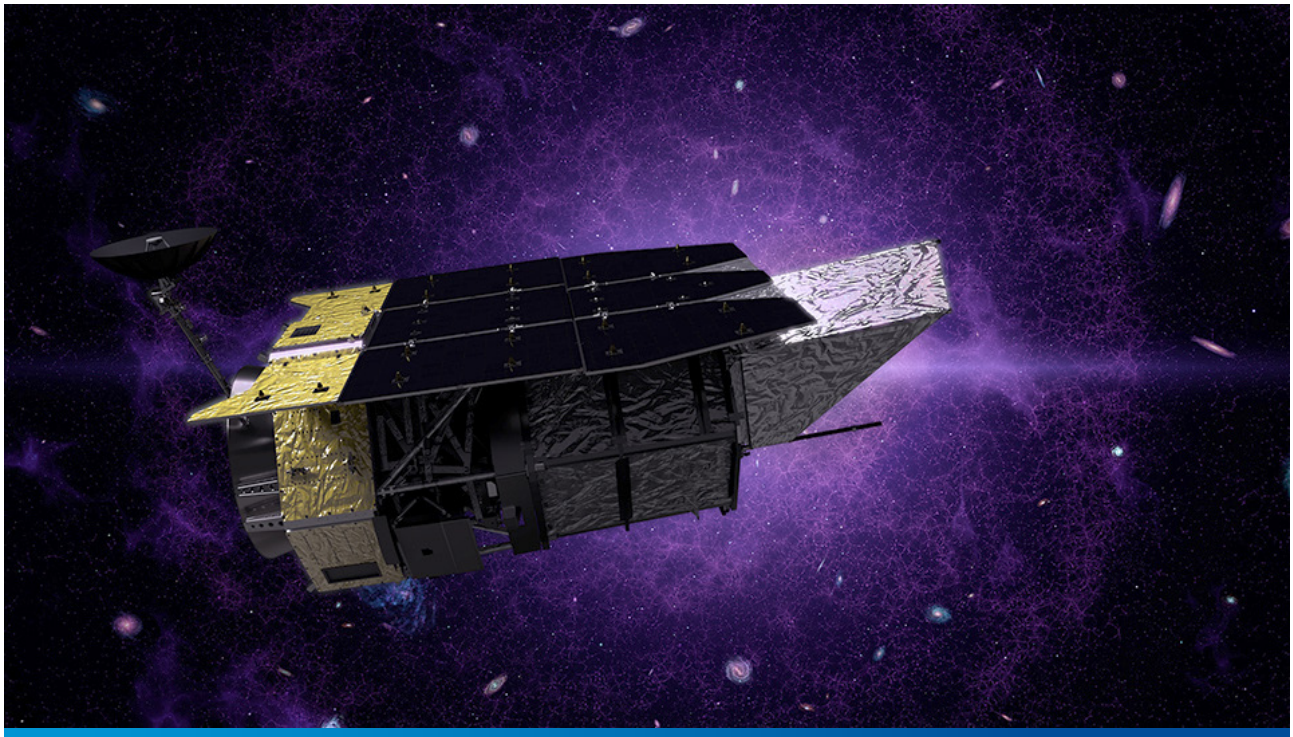
Department of Cosmology and Fundamental Physics

The Nancy Grace Roman Space Telescope (ROMAN), set for a late October 2026 launch, is a key mission aimed at making groundbreaking measurements related to dark energy properties. A primary objective of the mission is a groundbreaking measurement of dark energy properties. To achieve this, the Wide Field Instrument will conduct a High-latitude Time Domain Survey, focusing on Type Ia Supernovae (SNe Ia). The mission's reference survey uses six filters covering the wavelength range of 0.62–2.00 microns. The survey spans two years with 30-hour visits every five days, totalling six months of observation. Additionally, 800 externally observed low-redshift SNe Ia ($z < 0.1$) serve as anchors for cosmological analysis. The cosmology top-level requirements for the SNIa probe demand a sensitivity level of ~3 mag in each of roughly 4 bins over a redshift range of $0.5 < z < 2.0$. To achieve this, the survey aims to observe enough SNe Ia with a high signal-to-noise ratio, ensuring dominance by the intrinsic scatter floor. The strategy relies on rest-frame optical data within the observer-frame near-infrared range for the survey's redshift of interest. The survey utilises a two-tier strategy (wide and deep, for intermediate and high redshift) with prism spectroscopy for a portion of the area. Field choices focus on high ecliptic and Galactic latitudes, avoiding bright stars.

The ICE-CSIC Supernovae and stellar transients group is in charge of two working packages: the spectroscopic classification from the prism spectroscopy, and the SN Ia host galaxy characterisation.

Recent developments

In December 2022, NASA solicited proposals aimed at supporting the progress of and exploiting the scientific and technical data from ROMAN. A group of 51 researchers worked together to present a single proposal to develop a pipeline framework from pixel-to-cosmology, that will process ROMAN images and prism spectra, enabling the precision required to fully utilise SNe Ia as cosmological probes, and therefore constrain the true nature of dark energy. In July 2023, this proposal was among the 30 selected for funding.



Spacecraft Visualisation of the Roman Telescope.
Credits: GSFC/SVS.

22 Strobe-X

Senior Institute members involved: **M. Hernanz, A. Patruno**

Department of Astrophysics and Planetary Sciences

The Spectroscopic Time-Resolving Observatory for Broadband X-rays - Capturing the Universe in Motion (STROBE-X) is an X-ray mission proposal to NASA. Its aim is to study strong gravity in stellar mass to supermassive black holes and ultra-dense matter in neutron stars, with unprecedented effective area, high time-resolution, and good spectral resolution, while providing a powerful time-domain X-ray observatory. STROBE-X includes a Wide Field Monitor (WFM) inherited from LOFT ESA M3 pre-selected mission, and similar to the one for eXTP. STROBE-X was approved by NASA as a Probe-class Mission for the 2020-2030 US Decadal Survey. Its feasibility study, where ICE-CSIC participated with inputs for the WFM was performed in 2017-2019.

Recent developments

The STROBE-X proposal was submitted to NASA in November 2023, in response to NASA's "Astrophysics Probe Announcement of Opportunity". The eXTP/WFM group from ICE-CSIC actively participated in the WFM instrument part of the proposal.

6. Publications

6.1. Peer-reviewed Publications

In 2023, ICE-CSIC personnel participated in a total of 289 peer-reviewed publications, 48 more than the average in the period between 2019 and 2022.

All of these publications are directly accessible from an ADS-library linked from our webpage, and they are also listed below. The majority of the total of publications (around 95%) are in 1st quartile astrophysical journals, based on the SJR quartiles classification of 2022.[3]

	2018	2019	2020	2021	2022	Average 2019-2022	2023
Nº peer-reviewed papers	182	201	2221	231	313	241.5	289
ICE-CSIC led papers	33	31	38	34	74	44.2	63
% of papers with ICE-CSIC leadership	18.1	15.4	17.2	14.7	23.6	17.7	21.8

In 2023

289 peer-reviewed publications

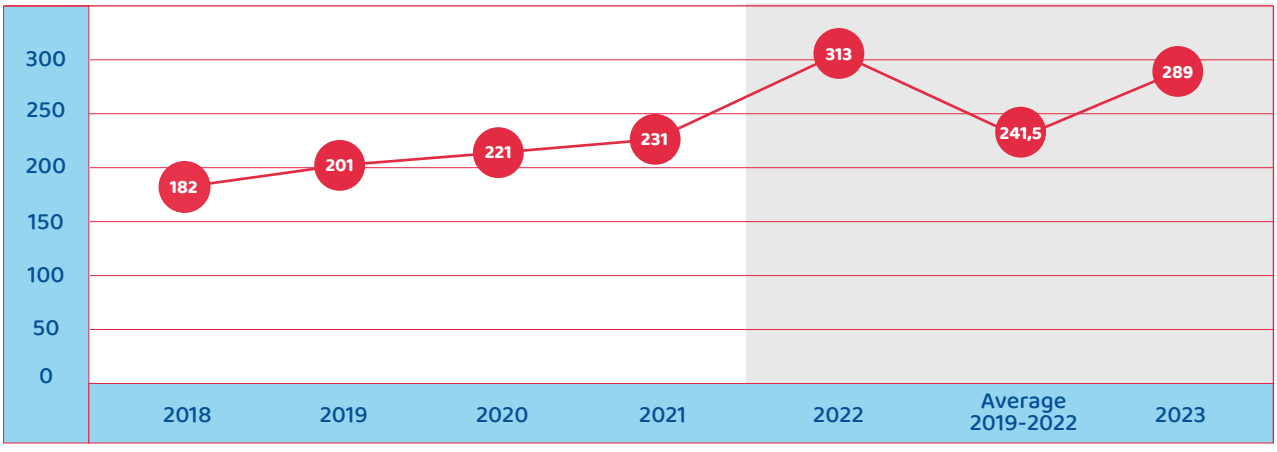
95% of publications in 1st quartile journals

5 publications in Nature

3 publications in Nature Astronomy

2,635 TOTAL CITATIONS

Nº peer-reviewed papers



[3] Full list of journals in the first quartile, according to the SJR classification: Astronomical Journal, Astronomy & Astrophysics, Astroparticle Physics, Astrophysical Journal, Astrophysical Journal Letters, Astrophysical Journal,Supplement Series, Atmospheric Chemistry and Physics, Engineering Applications of Artificial Intelligence, European Physical Journal C, Physics Reports, Faraday Discussions, GPS Solutions, Journal of Physics G: Nuclear and Particle Physics, Living Reviews in Relativity, Monthly Notices of the Royal Astronomical Society, Nature, Nature Astronomy, Physical Review C, Physical Review D, Physics Letters, Section B: Nuclear, Elementary Particle and High-Energy Physics, Physics of the Dark Universe, Publications of the Astronomical Society of Australia, Remote Sensing, and Universe.

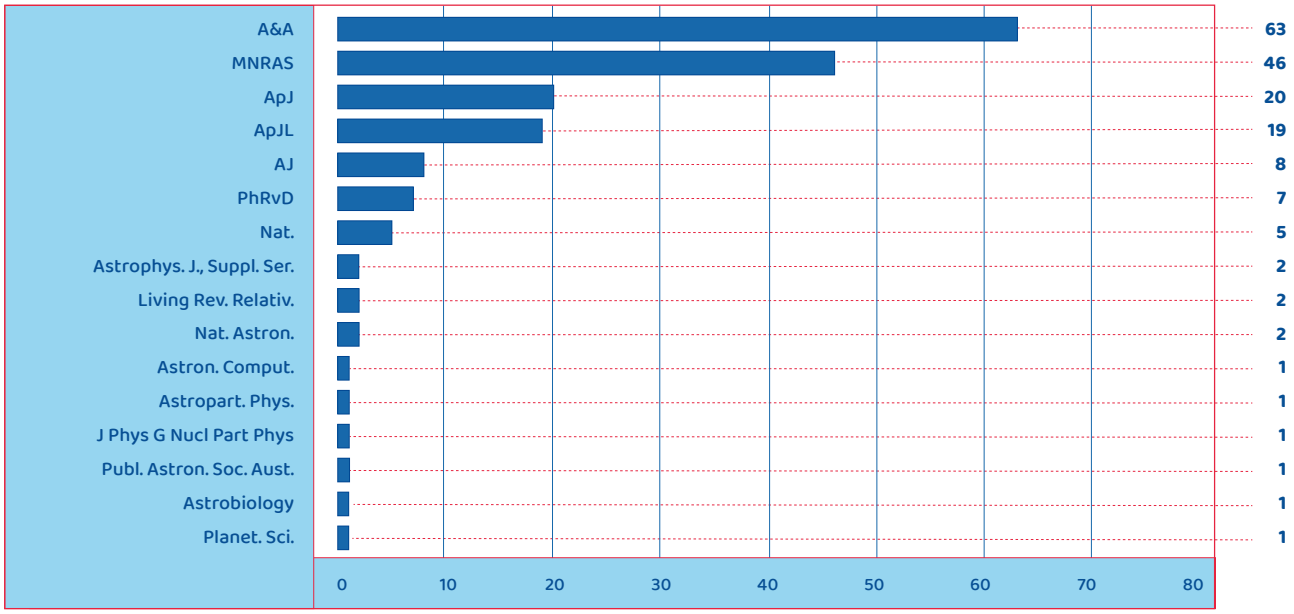
Full list of journals in the second quartile: Astrobiology, Astronomy and Computing, Frontiers in Physics, International Journal of Modern Physics D, Journal of Cosmology and Astroparticle Physics, Planetary Science Journal, Planetary and Space Science, and Symmetry.

Full list of journals in the third quartile: International Journal of Geometric Methods in Modern Physics.

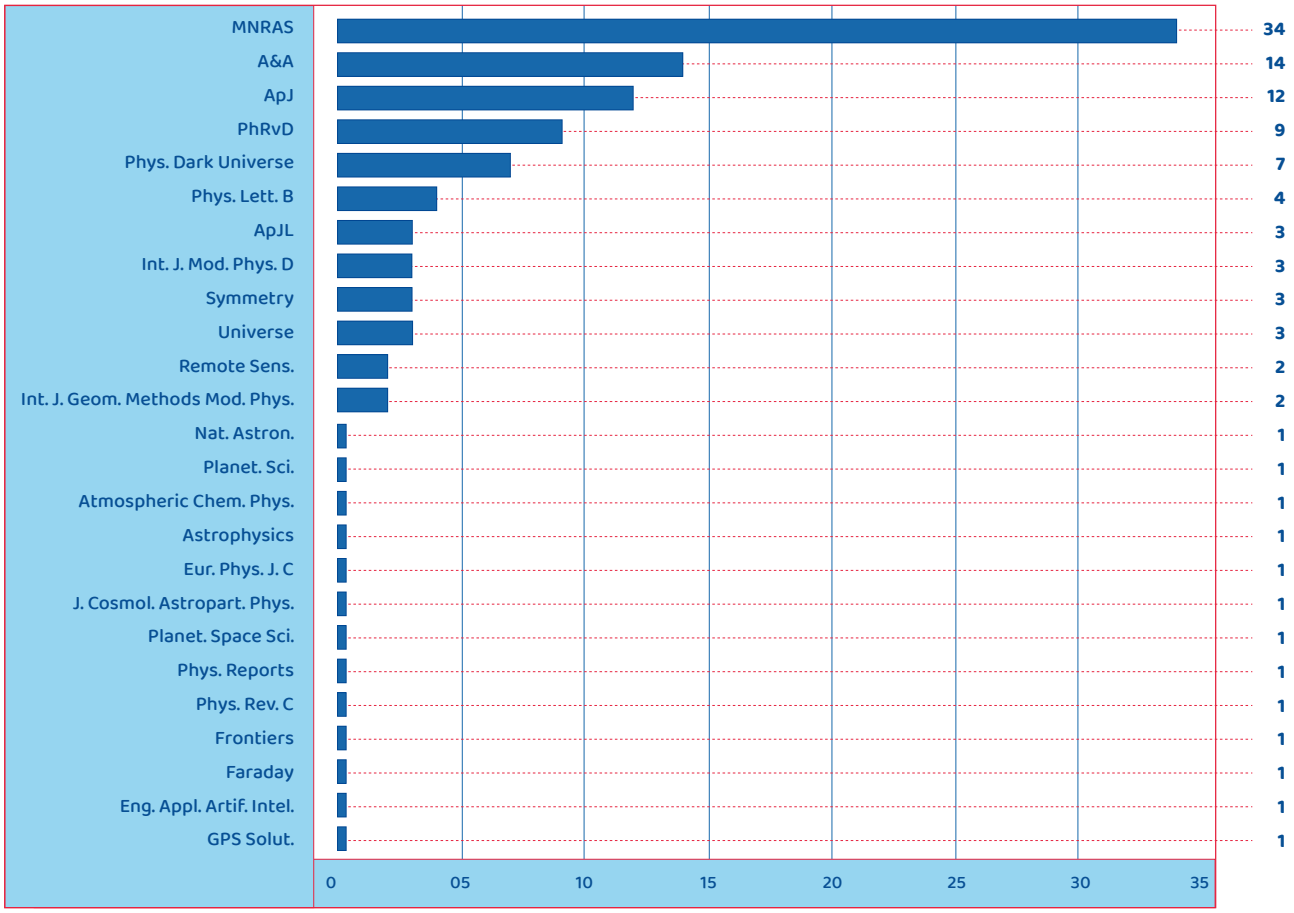
Full list of journals in the fourth quartile: Astrophysics.

Our research, in numbers

180 papers > 15 authors



109 papers ≤ 15 authors



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Astroparticle Physics

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Astrobiology

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285. Montesinos, V., Albaladejo, M., Nieves, J., & **Tolos, L.** (2023), *Properties of the $T_{cc}(3875)^+$ and $T_{c\bar{c}}(3875)^-$ and their heavy-quark spin partners in nuclear matter*, Physical Review C, 108, 035205, 10.1103/PhysRevC.108.035205.

Frontiers in Physics

286. Montaña, G., Ramos, À., **Tolos, L.**, & Torres-Rincon, J. M. (2023), *Recent progress on in-medium properties of heavy mesons from finite-temperature EFTs*, Frontiers in Physics, 11, 1250939, 10.3389/fphy.2023.1250939.

Faraday Discussions

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Engineering Applications of Artificial Intelligence

288. Nakhjiri, N., Salamó, M., Sànchez-Marrè, M., **Morales, J. C.** (2023), *A hybrid multi-start metaheuristic scheduler for astronomical observations, Engineering Applications of Artificial Intelligence*, 126, Part B, 106856, 10.1016/j.engappai.2023.106856.

GPS Solutions

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6.2. Books by ICE-CSIC members

Cover-art for El Universo.
Credits: Shackleton Books.

Cover-art for Una Ciutat en Marte.
Credits: Editorial Juventud.

Rea, N., *El Universo*, Shackleton Books (2023). Available in Spanish.

Kaid-Salah Ferrón, S., **Anglada-Escudé**, G., Sureda Anfres, M., *Una Ciudad en Marte*, Editorial Juventud (2023). Available in Spanish and Catalan.

7. Training

ICE-CSIC provides opportunities for international students and early career researchers to develop their professional careers including Master's programme and PhD opportunities as well as the organisation of the ICE-CSIC Summer School.

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

ICE-CSIC co-organises, together with 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.

In 2023, a total of 25 students were enrolled in the programme, from which a total of 11 students obtained their Master's degrees with theses supervised by ICE-CSIC researchers.

ICE-CSIC Faculty Mar Mezcua presenting the Postgraduate Programme in High Energy Physics, Astrophysics & Cosmology to students interested to enrol in the master's programme.
Credits: ICE-CSIC.

Defended Master's theses

1. **Galán Merino, I.**, *Predicting stellar parameters from stellar activity indices using neural networks.* Supervisors: Manuel Perger, Guillem Anglada-Escudé. Universitat Autònoma de Barcelona, 6/7/2023.

2. **Valderrama Flores, I.**, *Revealing hidden AGN in dwarf galaxies with radio observations.* Supervisor: Mar Mezcua. Universitat Autònoma de Barcelona, 7/7/2023.

3. **González Bañuelos, M.**, *Exploring the early spectra of SNe II and SNe IIb.* Supervisors: Claudia Gutiérrez, Lluís Galbany. Universitat Autònoma de Barcelona, 7/7/2023.

4. **Fernández Barbat, M.**, *Compact Stars with Dark Matter.* Supervisor: Laura Tolos. Universitat Autònoma de Barcelona, 20/7/2023.

5. **Pirvu Malanda, R.**, *The quest for radio emission from giant exoplanets and brown dwarfs.* Supervisor: Daniele Viganò, Simranpreet Kaur. Universitat Autònoma de Barcelona, 20/7/2023.

6. **Allande Gonzalez, J.**, *Kinematical study of the circumbinary gas around the BHB2007-11.* Supervisor: Josep Miquel Girart. Universitat Autònoma de Barcelona, 7/9/2023.

7. **Pérez Puigvert, X.**, *Cosmology and Galaxy Surveys, emulating the growth of structure in DESI.* Supervisor: Martin Crocce. Universitat Autònoma de Barcelona, 6/9/2023.

8. **Porqueras León, O.**, *Predicting stellar activity observables from cross-correlation functions using neural networks.* Supervisors: Manuel Perger, Guillem Anglada-Escudé. Universitat Autònoma de Barcelona, 6/9/2023.

9. **Tobella, B.**, *Improving the standardisation of SNe II as cosmological probes.* Supervisor: Tomás Müller Bravo. Universitat Autònoma de Barcelona, 7/9/2023.

10. **Valero Triviño, C. L.**, *SHOES SN Ia host galaxy properties with HOSTPHOT.* Supervisor: Lluís Galbany. Universitat Autònoma de Barcelona, 7/9/2023.

11. **Birsan, V. R.**, *Testing the nature of gravity with Black Holes.* Supervisors: Carlos Sopuerta, Michele Lenzi. Universitat Autònoma de Barcelona, 6/9/2023.

7.2. PhD Programme

ICE-CSIC hosts PhD candidates carrying out a programme of independent research supervised by ICE-CSIC researchers. During 2023, there were a total of 43 PhD students (9 women and 34 men) at the Institute, 15 from Catalonia, 9 from the rest of Spain, 4 from Europe and 15 from the rest of the world. From those, 15 started their PhD in 2023.

Defended PhD theses

1. **Dehman, C.**, *Unveiling the Physics of Neutron Stars - A 3D expedition into magneto-thermal evolution in Isolated Neutron Stars with MATINS.* Supervisors: Daniele Viganò, Nanda Rea, José A. Pons. Universitat Autònoma de Barcelona. 8/11/2023.

Clara Dehman at her PhD defence on 8 November 2023 at the UAB Science Faculty.
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. **Baghkhani, Z.**, *Simulating the Universe to exploit large cosmological surveys.* Supervisor: Francisco Javier Castander. Universitat Autònoma de Barcelona.

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

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

6. **Camacho, B.**, *Tackling Observational Cosmology challenges with Large Scale Structure.* Supervisor: Martin Crocce. Universitat Autònoma de Barcelona.

7. **Camacho, G. C.**, *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 Nadal, J.M.**, *Cosmología con cartografiados de galaxias.* Supervisor: Martin Crocce. Universitat Autònoma de Barcelona.

10. **Çoban, Ö. F.,** *Nova Explosions in X-and gamma-rays: Models and Observations.* Supervisor: Margarita Hernanz. Universitat Autònoma de Barcelona.

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

12. **D'Onofrio, S.**, *Modified gravity and early-universe cosmology.* Supervisor: Sergei Odintsov. Universitat Autònoma 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.* Supervisor: 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 Pallerola. 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. **Gascón, C.**, *Multiwavelength data-analysis techniques for high-contrast imaging of Terrestrial exoplanets.* Supervisors: Guillem Anglada, Ignasi Ribas. Universitat Autònoma de Barcelona.

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

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

22. **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.

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

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

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

26. **Ibrahim, A.**, *Búsqueda de eventos transitorios y púlsares en datos multifrecuencia.* Supervisor: Nanda Rea. Universitat Autònoma de Barcelona.

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

28. **Jiménez-Palau, C.**, *SNIa environments,* Supervisor: Lluís Galbany. Universitat Autònoma de Barcelona.

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

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

31. **Navarro, D.**, *Cosmología con mapas de galaxias.* Supervisors: Enrique Gaztañaga, Martin Crocce. Universitat Autònoma de Barcelona.

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

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

34. **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.

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

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

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

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

39. **Ronchi, M.**, *Desarrollo de código Machine Learning para el estudio de población de los púlsares Galácticos.* Supervisors: Nanda Rea, Vanessa Graber. Universitat Autònoma de Barcelona.

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

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

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

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

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

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

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

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

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

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

7.3. Summer School

The 6th ICE-CSIC Summer School devoted to the topic "Life Cycle of Dust" took place on 3-13 July 2023, and welcomed about 40 early-career researchers from 14 different countries.

The two-week long school was organised by Noemí Cortés, Josep Miquel Girart, Ciska Kemper, Álvaro Sánchez-Monge and José María Torrelles. The school programme included both theoretical lectures and hands-on sessions led by ICE-CSIC host lecturers and thirteen external experts from all over the world.

The programme focused on understanding the life cycle of dust, from its formation in dying stars to its aggregation into meteorites and planets around newly formed stars. The main goal was to provide junior astronomers with a solid foundation in the field of dust astrophysics covering a wide range of topics, including laboratory, observational and theoretical perspectives.

The participating master and PhD students were thus able to gain plenty of insights into this fascinating field. The lively interaction between students, eager to ask questions, and lecturers created a warm and welcoming atmosphere throughout the school. The feedback from the participating students was overwhelmingly positive.

These sessions were complemented with tours of the Institute's facilities, such as the ICE-CSIC meteorite collection, and a visit to the nearby ALBA Synchrotron.

Group picture 6th ICE-CSIC Summer School.
Credits: ICE-CSIC.

8. Conferences & seminars

8.1. Pizza Seminars

1. **Siudek, M.**, ICE-CSIC, *Unsupervised galaxy classification reveals new evolutionary pathways*, 20/1/2023.
2. **Lehmer, B. D.**, University of Arkansas, *X-ray Binary Populations in Galaxies Across Cosmic History*, 27/1/2023.
3. **Kopsacheili, M.**, ICE-CSIC, *New Diagnostics for the optical identification of Supernova Remnants*, 3/2/2023.
4. **Isern, J.**, ICE-CSIC, *Magnetic White Dwarfs*, 10/2/2023.
5. **Soriano, C.**, ICE-CSIC, *Hot Jupiters, why are they inflated?*, 17/2/2023.
6. **Sánchez-Monge, A.**, ICE-CSIC, *Towards a statistical understanding of the star formation process*, 24/2/2024
7. **Ashall, C.**, Virginia Tech, *Type Ia supernovae with the James Webb Space Telescope*, 3/3/2023.
8. **Müller Bravo, T. E.**, ICE-CSIC, *The effect of the host-galaxy environment on type Ia supernova standardisation*, 10/3/2023.
9. **Elias, A.**, ICE-CSIC, *Dynamo action and turbulence from localised random expansion waves / Long-term evolution of planetary magnetic fields*, 17/3/2023.
10. **Jiménez, C.**, ICE-CSIC, *Environments of SNe Ia using IFS*, 24/3/2023.
11. **Manuel, C.**, ICE-CSIC, *Chiral Transport Phenomena and Compact Stars*, 31/3/2023.
12. **Kaur, S.**, ICE-CSIC, *Radio emissions from exoplanets and a young stellar object*, 14/4/2023.
13. **Gavilanes, I.**, CSIC, *How we transfer knowledge at CSIC*, 21/4/2023.
14. **Vurgun, E.**, Universitat Politècnica de Catalunya, *Chandra studies of the globular cluster M28*, 28/4/2023.
15. **Cardellach, E.**, ICE-CSIC, *Swarms of nanosats: new opportunities for observational science*, 5/5/2023.
16. **Konstantinou, A.**, University of Crete, *The time-dependent B-rho relation in galaxy simulations with chemistry*, 12/5/2023.
17. **Bondarescu, R.**, Institut de Ciències del Cosmos, Universitat de Barcelona, ICCUB), *Compact Binaries through a lens: silent vs. detectable lensing with the LIGO-Virgo-Kagra Gravitational Wave Observatories*, 26/5/2023.
18. **Blagorodnova, N.**, Universitat de Barcelona, *Insights about binary's common envelope evolution with Luminous Red Nova transients*, 2/6/2023.
19. **Enriquez, F.**, ICE-CSIC, *The Snake of Physics: The Indispensable Role of Programming in Physics*, 9/6/2023.
20. **Elizalde, E.**, ICE-CSIC, *The scientific context of Einstein's visit to Catalonia and Spain*, 16/6/2023.
21. **Dempsey, J.**, Netherlands Institute for Radio Astronomy (ASTRON), *Harnessing the opportunities in the approaching radio astronomy renaissance*, 23/6/2023.
22. **Gaztañaga, E.**, ICE-CSIC, *Is cosmic expansion really accelerating?*, 22/9/2023.
23. **Cortes, P.**, National Radio Astronomy Observatory (NRAO), *The MagMAR project: First Results*, 29/9/2023.
24. **Rivero, J.**, ICE-CSIC, *Supporting a culture of public engagement at ICE-CSIC*, 6/10/2023.
25. **Mate, S.**, Tata Institute of Fundamental Research (TIFR), *Closing down the observation gap on millisecond to second timescale relativistic X-ray and radio transients*, 18/10/2023.
26. **Colom, M.**, Max-Planck-Institut für Radioastronomie, *Pulsar science with the MeerKAT radio telescope*, 27/10/2023.
27. **Huang, B.**, ICE-CSIC, *B-field Orion Protostellar Survey: Magnetised Envelopes in Orion*, 3/11/2023.
28. **Gourgouliatos, K.**, University of Patras, *Current flow in pulsar magnetospheres and the role of twist*, 10/11/2023.
29. **Rea, N.**, ICE-CSIC, *The wickedly cool and bursting stellar zombies*, 17/11/2023.
30. **Trejo, A.**, Instituto de Radioastronomía y Astrofísica (IRyA-UNAM), *The ngVLA, its science cases, and the current role of Mexico*, 24/11/2023.
31. **Tsang, D.**, University of Bath, *Nuclear Physics from Neutron Star Mergers*, 1/12/2023.

8.2. ICE-CSIC Colloquia

1. **Larsen, J.**, Project Stardust (University of Oslo, UiO), *In Search of Stardust: the discovery of the fresh "urban" cosmic dust*, 13/4/2023.
2. **Dempsey, J.**, Netherlands Institute for Radio Astronomy (ASTRON), *#MeNext? The quiet fears that silenced #MeToo*, 22/6/2023.

Special Christmas Seminar by Gustavo Deco (ICREA / UPF) on The Thermodynamics of Mind.
Credits: ICE-CSIC.

8.3. Invited seminars at ICE-CSIC

1. **Mendes, M.**, McGill University, *Cooling of transiently-accreting neutron stars to probe a quark phase*, 19/1/2023.
2. **Sáez, D.**, University of Valladolid, *Shadow formation around compact objects as observational proof in gravitational physics*, 13/2/2023.
3. **Husa, S.**, ICE-CSIC, *Development and application of waveform models for compact binary coalescence*, 16/2/2023.
4. **Angerhausen, D.**, *EHT Zurich, Professional Communication in Academia 101*, 4/5/2023.
5. **Angerhausen, D.**, *EHT Zurich, Searching for extraterrestrial life with LIFE : the Large Interferometer For Exoplanets mission concept*, 4/5/2023.
6. **Reboul-Salze, A.**, *AEI Postdam, Formation of fast-rotating magnetars: the magnetorotational instability in proto-neutron stars*, 31/5/2023.
7. **Stephens, I.**, University of Worcester, *Protoplanetary Dust Evolution via Polarisation Observations*, 20/6/2023.
8. **Ciardi, A.**, *Sorbonne University, Jets, shocks and cosmic rays: computer simulations and laboratory plasmas experiments*, 17/7/2023.
9. **Vargas, A.**, University of Melbourne, *Apparent dispersion in pulsar braking index measurements caused by timing noise*, 18/7/2023.
10. **O'Leary, J.**, University of Melbourne, *Measuring the magnetic dipole moment and magnetospheric fluctuations of SXP 18.3 with a Kalman filter*, 20/7/2023.
11. **Chatterjee, S.**, Indian Institute of Science Education and Research Bhopal, *Universal Relations and Speed of Sound in Neutron Stars*, 21/7/2023.
12. **Garland, I.**, Lancaster University, *Merger-Free co-evolution of supermassive black holes and their host galaxies*, 19/9/2023.

13. **Ayala, A.**, Universidad Nacional Autónoma de México (UNAM), *Relaxation time for the alignment between quark/antiquark spin and global vorticity in a rotating QCD medium*, 09/10/2023.

14. **Montes, M.**, Instituto de Astrofísica de Canarias (IAC), *Revealing the (optical) low surface brightness universe: The Intracluster Light*, 10/10/23.

15. **Haskell, B.**, Nicolaus Copernicus Astronomical Center, *The role of turbulence in magnetised neutron stars*, 9/11/2023.

16. **Gourgouliatos, K.**, University of Patras, *Current flow in pulsar magnetospheres and the role of twist*, 10/11/2023.

17. **Gillen, E.**, Queen Mary University of London, *Probing the early evolution of stellar and planetary systems*, 20/11/2023.

18. **Polkas, M.**, Donostia International Physics Centre, *Tidal disruption events in a cosmological context: the role of nuclear star clusters and massive black hole growth*, 22/11/2023.

19. **Qiu, Z.**, Keio University, *Dense Matter under a Magnetic Field via the Skyrme Model*, 29/11/2023.

20. **Deco, G.**, Universitat Pompeu Fabra, *The Thermodynamics of Mind*, 13/12/2023.

8.4. Workshops and meetings organised at ICE-CSIC

1. Visit of the Chinese delegation of the space mission eXTP, 27/2/2023.
2. The NewAthena Science case: SRDT/TPCs Meeting, 28-29/6/23.
3. ESA ARRAKIHS mission kick-off meeting, 26/7/2023.
4. Euclid Inter Science Task Force meeting, 2-4/10/2023.
5. Annual meeting of the LISA Spanish contribution, 5/10/2023.
6. Modified Gravity Theories Workshop, 10/10/2023 and 19/10/2023.
7. Euclid Cosmological Simulations SWG meeting 2023, 15-17/11/2023.

Group picture ESA ARRAKIHS mission kick-off meeting.
Credits: ICE-CSIC.

8.5. PhD seminars

1. PhD seminar November 2023: **Alemany, M.** (ICE-CSIC): *Optimising the sample selection for future photometric galaxy surveys*; **Peña, E.** (ICE-CSIC): *A Comprehensive Study of the Fireball Flux Over the Earth*, and **Jiménez, O.** *(ICCUB): The Large Magellanic Cloud dynamics with high resolution glasses,* 21/11/2023.
2. PhD seminar December 2023: **Biesdorf, C.** (UFSC): *Effective Models and Neutron Stars: how the modified MIT Bag model can better explain the quark matter and the existence of very massive compact stars*, and **Bernet, M.** (ICCUB): *Machine learning to learn? Rediscovering the Galactic Dynamics equations using data-driven tools*, 16/12/2023

8.6. ICE-CSIC Debates

1. **Graber, V.** and **Morales, J. C.**, *Space Tourism*, 13/1/2023.
2. **Anglada, G.** and **Parent, E.**, *Impact of Satellite Megaconstellations in astronomy*, 19/5/2023.

8.7. External conferences, seminars and congresses

1. **Rea, N.**, *Lstar Meeting*, Invited review, Bormio, Italy, 24/1/2023.
2. **Mezcua, M.**, *The seeds of the first supermassive black holes*, Spanish AGN meeting, online, Invited talk, 1/2/2023.
3. **Castander, F. J.**, *The Euclid Flagship Mock Galaxy Catalogue, Application of cutting-edge deep learning in astronomy*, New York, USA, Contributed talk, 30/1/2023, 03/02/2023.
4. **Tolos, L.**, *The Hadronic Equation of State for Neutron Stars*, Lee Institute of Shanghai, Shanghai, China, Online talk, 14/2/2023.
5. **Sopuerta, C.F.**, *Observant ones gravitacionals des de l'espai amb LISA. Un nou repte per a la relativitat general d'Einstein*, Jornada commemorativa del centenari de la visita d'Albert Einstein, RACAB, Barcelona, Spain, 23/2/2023.
6. **Fosalba, P.**, *Cosmologia amb cartografiats de galàxies: la missió Euclid*, Jornada commemorativa del centenari de la visita d'Albert Einstein, RACAB, Barcelona, Spain, 23/2/2023.
7. **Cardellach, E., Rius, A.**, *Aplicacions pràctiques de la teoria de la relativitat: els GNSS*, Jornada commemorativa del centenari de la visita d'Albert Einstein, RACAB, Barcelona, Spain, 23/2/2023.
8. **Rea, N.**, *Challenge 10: Understanding matter and radiation under extreme conditions*, Workshop CSIC Strategic Theme "Understanding the basic components of the Universe, its structure and evolution", CSIC, Madrid, Spain, 22-23/2/2023.
9. **Cardellach, E.**, *La Terra des de l'espai: creant noves tècniques de teledetecció per satèl·lit*, Congrés Dones, Ciència i Tecnologia WSCITECH23, Terrassa, Spain, 3/3/2023.
10. **Manuel, C.**, *Lectures on Field Theory Methods for Hot and Dense Nuclear Matter, XXI Jorge André Swieca Summer School on Theoretical Nuclear Physics*, Angra dos Reis, Brazil, Invited review, 6/3/2023, 10/3/2023.
11. **Trigo-Rodríguez, J. M.**, *Unveiling early accretion from the laboratory study of carbonaceous chondrites: clues for ongoing processes in protoplanetary disks*, PLANET-ESLAB-2023: Understanding planets in the solar system and beyond, Invited talk, ESA-ESTEC, the Netherlands, 20/3/2023.
12. **Tolos, L.**, *Heavy flavour in a hot bath*, HERAUS meeting, Bad Honnef, Germany, Invited talk, 3/4/2023.

13. **Kemper, F.**, Bouwman, J., *Database of optical constants and dust models, Interstellar Soot and Sand with JWST*, Leiden, the Netherlands, Invited talk, 25/4/2023.

14. **Kemper, F.**, Gordon, K., *Historical overview of available tools to interpret data, their methods and limitations*, Interstellar Soot and Sand with JWST, Leiden, the Netherlands, Invited talk, 26/4/2023.

15. **Tolos, L.**, *Strangeness in Nuclei and Neutron Stars*, GRASP opening meeting, Utrecht, the Netherlands, Invited talk, 23/5/2023, 25/5/2023.

16. **Mezcua, M.**, *The seeds of the first supermassive black holes*, Munich Joint Astronomy Colloquium, Max-Planck-Institut für Extraterrestrische Physik/Max-Planck Institut für Astrophysik/European Southern Observatory, Garching bei München, Germany, Invited talk, 25/5/2023.

17. **Kemper, F.**, *Calibrating submillimeter dust emissivities with the Nearby Evolved Stars Survey* (NESS), JCMT Users Meeting, London, United Kingdom, Contributed talk, 31/5/2023.

18. **Trigo-Rodríguez, J. M.**, *Interacción Tierra-espacio: Detección de impactos de asteroides y reentradas, oportunidades científicas y amenazas para la sociedad.* Jornada de colaboración científica en seguridad y defensa, CSIC, Madrid, 31/5/2023.

19. **Lenzi, M.**, *On the dynamics of perturbed Black Holes: Applications and Implications (Part 2)*, Advanced Relativity Meeting 23 (Jarramplas 23), Almagro, Spain, Contributed talk, 8/6/2023, 11/6/2023.

20. **Kemper, F.**, *The Interstellar Dust Reservoir in Galaxies*, ICCUB, Barcelona, Spain, 8/6/2023.

21. **Sopuerta, C.**, *On the dynamics of perturbed Black Holes: Applications and Implications: Part I*, Advanced Relativity Meeting 2023 (Jarramplas 2023), Almagro, Spain, Contributed talk, 9/6/2023.

22. **Rea, N.**, *Neutron stars transients*, X-ray Universe 2023, Invited review, Athens, Greece 14/6/2023.

23. **Rea, N.**, *Long period radio transients*, SKA meeting, Invited review, Kerastary, Greece 16/6/2023.

24. **Elizalde, E., Odintsov, S.**, *Symmetry 2023 - The 4th International Conference on Symmetry 2023*, Barcelona, Spain, Organisers, 21-23/6/2023.

25. **Galbany, L.**, *Supernova science with the JWST*, The 18th National Festival in Popular Astronomy, Algeria, 22-24/6/2023.

26. **Tolos, L.**, *Strangeness in Neutron Stars*, Meson2023, Krakow, Poland, Invited talk, 24/6/2023.

27. **Manuel, C.**, *Helicity conservation laws in relativistic plasmas*, 19th International Conference on QCD in Extreme Conditions, Coimbra, Portugal, Contributed talk, 26/7/2023, 28/7/2023.

28. **Elizalde, E.**, *Consideracions científiques al voltant de la visita d'Einstein a Catalunya (1922-1924), El naixement de la cosmologia moderna: la important aportació d'Einstein*, Universitat Catalana d'Estiu, Barcelona, Spain, 23/8/2023.

29. **Lenzi, M.**, *On the dynamics of perturbed Black Holes, XXV SIGRAV Conference on General Relativity and Gravitation*, Trieste, Italy, Contributed talk, 4/9/2023, 8/9/2023.

30. **Elizalde, E.**, *True Story of Modern Cosmology*, Cosmology and the Quantum Vacuum, Benasque, Spain, 10-16/9/2023.

31. **Manuel, C.**, *Effective field theories for hot relativistic plasmas, Thermalization, from Cold Atoms to hot Quantum Chromodynamics*, Seattle, USA, Invited talk, 11/9/2023, 18/9/2023.

32. **Rea, N.**, Flatiron Meeting on Fast Radio Bursts, Invited review, New York, USA 11/9/2023.

33. **Torres, D. F.**, Pulsar wind nebulae beyond reverberation, TeVPa 2023, Contributed talk, Naples, Italy, 11-15/9/2023.

34. **Torres, D. F.**, *LS I 61 303 as a gamma-ray pulsar*, Variable Galactic Gamma-Ray Sources VI, Invited talk, Innsbruck, Austria, 12-14/9/2023.

35. **Sopuerta, C.**, *Sources of gravitational waves in the Deci-hertz band, ELGAR, a future European Laboratory for Gravitation and Atom-interferometric Research*, Bordeaux, France, Contributed talk, 8-10/11/2023.

36. **Cardellach, E.**, *GNSS Polarimetric Radio Occultations: a novel sounding technique to simultaneously sense thermodynamics and hydrometeors*, Météo France, Toulouse, France, 19/10/2023.

37. **Cardellach, E., Padullés, R., Paz, A.**, *GNSS Polarimetric RO aboard PAZ: Science Applications*, TAIWAN International Assembly of Space Science, Technology, and Industry (TASTI 2023), Taipei, China Taiwan, Invited talk, 30/10/2023, 3/11/2023.

38. **Cardellach, E., Padullés, R., Paz, A.**, *GNSS Polarimetric RO: A New Technique Remote Sensing Technique*, TAIWAN International Assembly of Space Science, Technology, and Industry (TASTI 2023), Taipei, China Taiwan, Invited review, 30/10/2023, 4/11/2023.

39. **Ribas, I.**, *Habitable planets in the solar neighbourhood*, XXXVIII Trobades Científiques de la Mediterrània - Josep Miquel Vidal, Menorca, Spain, 6-8/11/2023.

40. **Morales, J. C.**, *Exoplanet atmospheres challenges,* XXXVIII Trobades Científiques de la Mediterrània - Josep Miquel Vidal, Menorca, Spain, 6-8/11/2023.

41. **Kemper, F.**, *Unusual optical dimming and near-infrared brightening in ASASSN-21qj: exocometary breakup or colliding ice-giants?*, XXXVIII Trobades Científiques de la Mediterrània - Josep Miquel Vidal, Menorca, Spain, 6-8/11/2023.

42. **Fosalba, P.**, *Cosmology with Euclid: from promise to reality, IX Meeting on Fundamental Cosmology*, IAC, Tenerife, Spain Invited Talk, 22/11/2023.

43. **Mezcua, M.**, *Intermediate-mass black holes: current status and future prospects*, Intermediate-mass black holes 2023 meeting, Invited review talk, Belize, 2-5/12/2023.E

44. **Elizalde, E.**, *Una visió contemporània i actual de les teories de la relativitat i la visita d'Einstein a la Catalunya de 1923*, IMUB colloquium, Institut de Matemàtica, Universitat de Barcelona, Barcelona, Spain, 20/12/2023.

9. Projects

In 2023, ICE-CSIC received competitive funding for 17 new scientific projects for a total of around 5.05 million euros, distributed in 4.4 million euros from national funding, 346.4 thousand euros from European funding and 305.1 thousand euros from other funding sources. Other 32 projects have also been active since the year 2022 for a total of 49 active projects in 2023.

9.1. New projects

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

2. **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

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

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

5. **Project code:** PID2021-126436OB-C22
   Title: Becas de postdoctorado Junior Leader 2023
   IP: Alarcón, A.
   Funding Source: Fundación La Caixa

6. **Project code:** PID2022-139427NB-I00
   Title: Effective theories of strong nuclear interactions under extreme conditions
   IPs: Manuel, C., Tolos, L.
   Funding Source: AEI-MICIN

7. **Project code:** PID2022-137674NB-I00
   Title: Contribución española a LISA: desarrollo del sistema de diagnóstico y explotación científica
   IPs: Nofrarias, M., Sopuerta, C.
   Funding Source: AEI-MICIN

8. **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

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

10. **Project code:** 4000141951/23/NL/AS/nh
    Title: Processing of Wideband GNSS-R Signals Received at Spaceborne Altitude (WB_GNSSR)
    IP: Li, W.
    Funding Source: European Space Agency (ESA)

11. **Project code:** 4000142425/23/NL/AS/ov
    Title: HydroSwarm
    IP: Cardellach, E.
    Funding Source: European Space Agency (ESA)

12. **Project code:** 4000135180/21/I-DT-bgh
    Title: Data Evaluation Agreement between SPIRE GLOBAL LUXEMBOURG S.A R.L. i IEEC (PROGRES)
    IP: Cardellach, E.
    Funding Source: European Space Agency (ESA)

13. **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

14. **Project code:** PRETTY-NTNU
    Title: Passive Reflectometry and Dosimetry (PRETTY) IOD Cubesat Mission (PRETTY)
    IP: Cardellach, E.
    Funding Source: European Space Agency (ESA)

15. **Project code:** SGR-Cat2021-01269
    Title: MAGNESIA
    IP: Graber, V.
    Funding Source: Generalitat de Catalunya

16. **Project code:** SGR-Cat2021-01526
    Title: Stellar and exoplanetary astrophysics from space
    IP: Serenelli, A.
    Funding Source: Generalitat de Catalunya

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

9.2. Ongoing Projects

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

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
   IP: Cardellach, E., Ribó, S.
   Funding Source: AEI-MICIN

8. **Project code:** TED2021-129812B-I00
   Title: Medición de humedad del suelo a profundidad utilizando drones
   IP: 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
    IP: Torres, D. F., Patruno A.
    Funding Source: AEI-MICIN

11. **Project code:** PID2021-124581OB-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

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:** 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
IP: 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:** PID2019-111317GB-C31
Title: Dark Energy Cosmological Surveys, enabling Euclid
IPs: Castander, F. J., Fosalba, P.
Funding Source: AEI-MICIN

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

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

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

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

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

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

10. Awards & Distinctions

10.1 Awards

Josep M. Trigo-Rodríguez receives the Joan Lluís Vives award for his book *La Terra en perill*

The ICE-CSIC and IEEC researcher Josep M. Trigo-Rodríguez received the Joan Lluís Vives prize for the university edition for the best science and technology book for La Terra en perill. The impact of asteroids and comets. The book, available in Catalan, Spanish and English, is part of the popular science collection Catalysis, and explains how the scientific community prepares to face the impact of potentially dangerous asteroids and how the study of impact craters and other evidence has allowed to deepen the knowledge of its effects in the past of our planet.

10.2 Distinctions

1. **Diego F. Torres** recognised as Best Physics Scientist in Spain by Research.com, more information.
2. **Sergei Odintsov** recognised as Highly-Cited Researcher 2023 by Clarivate, more information.

ICE-CSIC researcher Josep María Trigo-Rodríguez with a stony-iron meteorite in his hand.
Credits: César Hernández.

11. 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.

11.1. Communication

One of the highlights of ICE-CSIC communications activities was the publication of 41 pieces in 2023 (18 scientific news, 12 institutional news and 11 outreach news) [see Section 12 for more details]. From those, we coordinated 17 press releases in collaboration with the CSIC and IEEC Communication Offices to reach out to press at regional, national and international level. These led to a total of 523 appearances in media outlets [6].

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 (formerly Twitter), YouTube, LinkedIn and Instagram, being the latter opened in June 2023.

In late 2023, an online ICE-CSIC newsletter was launched. The newsletter, published quarterly, aims to disseminate the latest news, announcement of events, jobs, publications and many other updates about the Institute. In 2023, the first two newsletters were published in September and December.

Overall, ICE-CSIC central communication activities had a total reach of around 477,000 people (see breakdown in infographic), with an extended reach of around 84.5 million people considering media coverage[4].

For relevant projects, the ICE-CSIC Communication and Outreach Office also launched specific campaigns preparing different actions for multiple platforms to reach wider audiences. For instance, around the launch of ESA's Euclid mission in early July, press briefings were prepared to alert Spanish media about the Institute's contributions and we produced, together with IFAE, a video showcasing the Institute's contributions to Euclid. A social media campaign was launched to boost our new Instagram account at the time and published an article in the Spanish *Astronomía* magazine. The campaign had a strong reach online, including over 35,000 views for the video produced and served to bring the contributions from ICE-CSIC to several of the main Spanish media, including the use of footage of the video in *3Cat* news.

During the year the ICE-CSIC Communication and Outreach Office also coordinated press inquiries for ICE-CSIC researchers and received visits from *TVE* and *3Cat* reporters to record interviews for their news services as well as the newscast service for children *InfoK* that featured a programme about ICE-CSIC researchers.

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

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

ICE-CSIC Communication Impacts

Web

Google analytics, data from 22 June (when installed) to 31 december 2023.

Views **78,315**

Users **14,368**

Followers

2,274

Post impressions **393,100**

Followers

352

Post impressions **11,266**

Subscribers

506 (+342 from 2022)

Views **42,900** (495% more than 2022)

Followers

831

Post impressions **30,393**

TOTAL VIEWS & IMPRESSIONS 477,000[5]

Press impacts[6]

Number of press impacts **523**

Audience **84.5 Million**

[5] This figure is the result of the addition of the ICE-CSIC website views, YouTube views, Twitter post impressions, Instagram post impressions and LinkedIn post impressions.

[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.

11.2 Outreach

In 2023, 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 the period 2021-2025, ICE-CSIC will work together with the school and an expert in didactics to co-create and implement inquiry-based astronomy activities for 3 to 11 year old students, as well as further activities with a scientific and outreach impact for the town of Igualada.

This programme involved 27 ICE-CSIC members (8 women and 19 men), composed of 3 coordinators and 24 researchers and technical staff that supported teachers to bring astronomy topics to the classroom and organised visits to perform hands-on activities with the students. To further support the teachers, two teacher trainings were held during the year about the Sun and Galaxies.

Group picture of ICE-CSIC researchers and teachers of Gabriel Castellà i Raich school during a visit of ICE-CSIC researchers to perform astronomy hands-on activities with the students.
Credits: ICE-CSIC.

Other important Magnet activities featured a special event at the school for the UN International Day of Women and Girls in Science around February 11th, in which ICE-CSIC female researchers participated; the organisation of hands-on activities in events at the Museu de la Pell d'Igualada in February and November; and our participation at the European Researchers' Night activity at the school, where students and families enjoyed solar observations and hands-on activities.

Starting the 2023-2024 academic year, the ICE-CSIC Communication & Outreach Office collaborates with the ESA CESAR project, which organises online training courses for teachers on topics related to space sciences. The first of these teacher trainings was organised in November 2023 with the participation of around 100 teachers. In the framework of the CESAR project, we also participated in organising the ESA Galileo Teacher Training Programme Workshop at ESAC (Madrid) in September with the participation of 30 teachers.

As part of the CSIC Scientific Education Group, the ICE-CSIC Communication and Outreach Office took part in the design and planning of 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 will take place in April 2024 and it is addressed to scientific and technical personnel involved -or who wants to be involved in the future- in outreach and educational activities. It will be an online course taught by teachers, experts in didactics and professionals involved in the educational field.

We also joined the Amanar programme bringing astronomy closer to young Sahrawis spending their summer in Spain with host families in the framework of the 'Holidays in Peace' programme. The Amanar

Project, originated by the GalileoMobile initiative, collaborated with several astronomy institutions around Spain throughout the summer, arranging outreach activities for Sahrawi boys and girls and their host families in cities such as A Coruña, Granada, Madrid, Sagunto and Tenerife. In the Barcelona province, our Institute, together with the Castelldefels Astronomical Group (Astrofels), co-organised hands-on activities and telescope observations held in Castelldefels, at the Astrofels association observatory, located in the Cal Ganxo Centre for Environmental Activities, which was attended by 12 boys and girls together with their host families.

On the occasion of the International Day of Women and Girls in Science on February 11th, the ICE-CSIC Outreach & Communication office organised an online event featuring talks by female researchers at our Institute about their work and their motivation to become scientists. A follow-up event was co-organised with the Institute's Equity Committee on March 8th to commemorate International's Women Day where women working at the Institute from different generations and fields (research, engineering, administration) shared the experiences and struggles found in their career paths. In addition, 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 SEA.

Speakers at the 11F International Day of Women and Girls in Science Event at ICE-CSIC. From left to right: Dane Cross, Maria Kopsacheilli and Claudia Soriano.
Credits: ICE-CSIC.

For the European Researchers' Night, besides the participation on the Magnet activity, the Institute joined once more other CSIC centres in Catalonia, organising a Science Slam event, where CSIC scientists spoke about their research projects. This time, the event focused on PhD researchers. And finally, we organised, in collaboration with AstroUAB (University's astronomy club), a solar observation open to the general public on the UAB campus.

Within the framework of CSIC's Science and Technology Week in November, we organised and participated in several activities for the general public, as well as for university and school audiences, including a screening at the UAB Cinema of the *A Refuge in the Stars* documentary about the conflict in Western Sahara through the experience of the astronomy outreach project Amanar; night-sky observations at the UAB campus; and a visit to an elderly residence to perform night observations with telescopes and share curiosities about astronomy with residents and their families.

To promote the Institute's activities and especially the opportunities to work at our Advance Engineer Unit, on April 26th we joined the MEMEnginy congress organised by UAB's Engineer Faculty, with a stand to assist students interested in pursuing a career in Engineering. This networking event serves to put engineering students in contact with institutions and companies to learn about potential job opportunities. Our participation was a success and we were able to engage with around 150 students.

To foster discussion within the Institute, two debates were organised in January and May. The first ICE Debate covered the topic of space tourism where ICE-CSIC researchers Vanessa Graber and Juan Carlos Morales presented opposing points of view on the matter and opened the debate to all the Institute's members. The second one focused on the impact of satellite mega constellations and was led by ICE-CSIC researchers Emilie Parent and Guillem Anglada. Both ICE debates engaged the participation of around 70 people each.

Solar observations at the UAB Bellaterra Campus.
Credits: ICE-CSIC.

Finally, the ICE-CSIC Communication & Outreach Office members presented the Institute's communication and outreach initiatives in conferences at national and international level, such as the I Congreso de Inclusión del CSIC (Madrid, Spain, 2-3 October), the IX Congreso de Comunicación Social de la Ciencia (Granada, Spain, 25-27 October) and the IAU's Shaw Education Workshop (online, 29 November - 1 December).

ICE-CSIC stand at the MEMEnginy 2023 student fair.
Credits: ICE-CSIC.

11.2.1. 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 53 outreach activities and talks organised by external institutions.

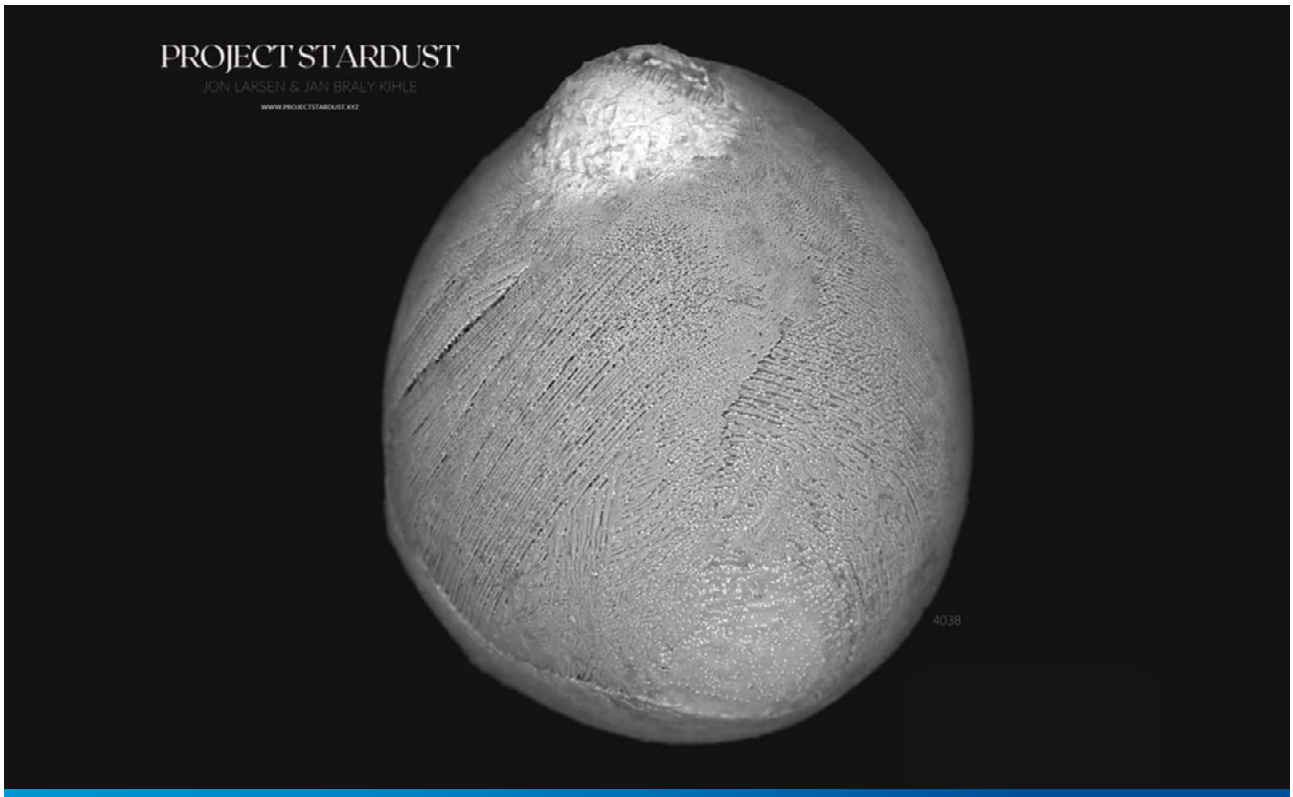
Find below some of the main outreach initiatives by ICE-CSIC researchers during 2023.

The Spanish Meteor Network (SPMN)

The Spanish Meteor Network (SPMN) is a citizen science project coordinated by Josep M. Trigo-Rodríguez, principal investigator of ICE-CSIC's Meteorite, Minor Bodies and Planetary Sciences Group. The 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. Continuous operations allow the SPMN to record many sporadic fireballs, but also these originated in meteoroid streams which are produced by periodic comets and asteroids.

2023 was a terrific year with excellent weather conditions and also exhibiting many meteor shower displays. In addition to the Lyrids, Eta Aquarids, Delta Aquarids, Perseids, Orionid and Taurids, the SPMN imaged tens of fireballs of the Leonids and the Geminids. In fact, November and December had impressive displays of bright fireballs that made both months the most populated: 314 and 365 fireballs respectively, together with August in which we recorded 358. In total, our SPMN database incorporated 2,791 new bolides. It is an absolute record in 28 years of operations of our project.

In addition, in the framework of the Project Stardust, the expert in urban micrometeorites Jon Larsen collaborated with Josep M. Trigo-Rodríguez to look for micrometeorites at the rooftops of ICE-CSIC and several other buildings at UAB campus. They found a barred olivine type micrometeorite at the centre's roof.



Laboratory image of micrometeorite found at ICE-CSIC rooftop.
Credits: Jon Larsen.

La Veu Còsmica audiovisual podcast

La Veu còsmica is an audiovisual podcast in Catalan that combines science, music and poetry. Throughout 12 chapters of 25 minutes, ICE-CSIC and IEEC researcher Lluís Galbany, accompanied by the poet Esteve Plantada and the musician Joan Garriga, interviews experts on different topics in astrophysics and cosmology, such as space exploration, black holes, dark matter or supernovae. Among the experts interviewed are ICE-CSIC researchers Guillem Anglada-Escudé, Josep M. Trigo-Rodríguez, Mar Mezcua, and Nanda Rea.

ICE-CSIC researcher Nanda Rea interviewed by ICE-CSIC researcher Lluís Galbany, poet Esteve Plantada and musician Joan Garriga at the La Veu Còsmica podcast.
Credits: La Veu Còsmica.

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 proposes a visit to the cosmos using gravity as a common thread. The first four chapters are free online on *RTVE Play*. The first 8 chapters are also available on *Filmin*. 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 and Víctor Martín.

Blogs

- Dark Cosmos, a blog by the ICE-CSIC Extragalactic Astrophysics and Cosmology Group.
- Blog by Josep M. Trigo-Rodríguez on The Conversation.

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:

- La deu de l'únic vers, a blog by Lluís Galbany on *Divulcat*.
- Exploració del Cosmos, a blog by Jordi Isern on *Divulcat*.
- Obrint els ulls..., a blog by Emilio Elizalde on *Divulcat*.
- Nazca en la distància, a blog by Estel Cardellach on *Divulcat*.
- Ciències planetàries i meteorits, a blog by Josep M. Trigo-Rodríguez on *Divulcat*.
- Exoplaneta blau, a blog by Guillem Anglada-Escudé on *Divulcat*.

12. News

January

20 The Institute of Space Sciences goes on its first strategy retreat after the pandemic

January

30 Supermassive black holes found in distant dwarf galaxies

February

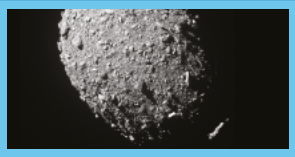
22 CARMENES project boosts the number of known planets in the solar neighbourhood

February

28 A Chinese delegation of eXTP satellite visits ICE-CSIC to discuss the mission's advances

March

01 More than 5 million kilos of material released after the DART probe collision with Dimorphos asteroid



March

14 A model of the Universe explains its accelerated expansion without the need for dark energy

April

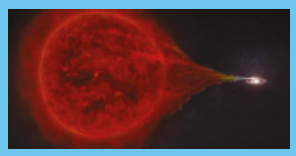
20 ICE-CSIC participates at the UAB's technological congress #MEMEnginy2023

May

12 Astronomers reveal the largest cosmic explosion ever seen

May

17 Gamma-ray emission from a recurrent nova confirms a 2006 prediction

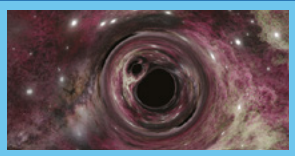


June

13 DESI Early Data Release Holds Nearly Two Million Objects

June

29 Unveiling the origins of merging black holes in galaxies like our own



June

30 The Euclid telescope takes off to explore the dark Universe

July

03 The ICE-CSIC holds its 6th Summer School: two weeks focused on the Life Cycle of Dust

July

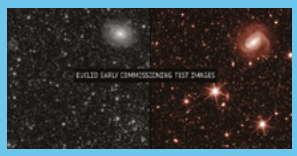
19 Astronomers discover a new type of stellar object hiding in plain sight

July

28 ESA ARRAKIHS mission kick-off at the Institute of Space Sciences

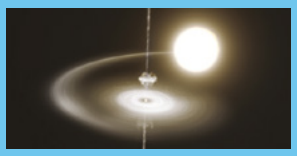
July

31 Euclid test images tease of riches to come



August

30 Astronomers unravel a pulsar's bizarre behaviour



September

08 Diego F. Torres steps down as director of the Institute of Space Sciences

September

18 The Roman Space Telescope to be launched in 2027 to discover the true nature of dark energy

October

04 ICE-CSIC holds the first Euclid Inter Science Task Force meeting after its launch

October

05 ICE-CSIC holds the Annual meeting of the LISA Spanish contribution

October

11 ESA's PRETTY mission, a nanosatellite to monitor sea and ice from space

November

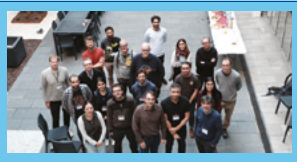
07 Euclid release its first images: the dazzling edge of darkness

November

15 A stellar corpse shows signs of life through unprecedented flares

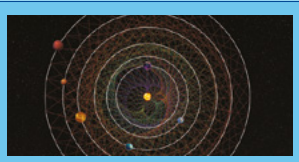
November

23 ICE-CSIC holds the Euclid Cosmological Simulations SWG meeting 2023



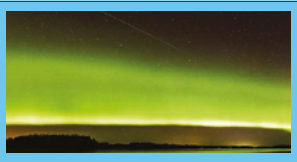
November

29 Astronomers discover six planets thanks to their synchronised orbits



December

14 Astronomers discover a rock reaching Earth's atmosphere



December

18 A micrometeorite found at the rooftop of the Institute of Space Sciences

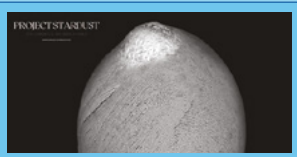


Image Credits

ICE-CSIC participation in Missions and Experiments Infographic (page 29)

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

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

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

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

5. **CHEOPS**
   Artist impression of Cheops, the Characterising Exoplanet Satellite, with an exoplanet system in the background. Credits: ESA/ATG medialab.

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

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

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

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

10. **EINSTEIN PROBE**
    Einstein Probe artist impression. Credits: CAS.

11. **EINSTEIN TELESCOPE**
    Einstein Telescope artist impression. Credits: Einstein Telescope Collaboration.

12. **EUCLID**
    Illustration of the Euclid space mission in space. Credits: ESA/ Euclid/Euclid Consortium/NASA. Galaxies in the background: NASA, ESA, and S. Beckwith (STScI) and the HUDF Team.

13. **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.

14. **FERMI**
    Illustration of the Fermi Gamma-ray Space Telescope, which has now been studying the extreme universe for a decade. Credits: NASAÕs Goddard Space Flight Center/ Conceptual Image Lab.

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

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

17. **LISA**
    The three LISA spacecraft will be placed in orbits that form a triangular formation with centre 20° behind the Earth and side length 5 million km. (The figure showing the formation is made to scale). Credits: NASA.

18. **PAU**
    PAUCam. Credits: PAUCam.

19. **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), to test the capabilities of polarimetric radio occultation signals to sense precipitation events. Credits: Hisdesat.

20. **PLATO**
    Artist's impression of ESA's PLATO spacecraft. Credits: ESA/ ATG medialab.

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

22. **22 STROBE-X**
    Artist's impression of Strobe-X spacecraft. Credits: NASA.

ICE-CSIC News infographic (pages 90 and 91)

1. **20/1/2023**
   Group picture of the institute's members during the strategy retreat in Santa Maria de Montserrat Abbey.
   Credits: ICE-CSIC.

2. **30/1/2023**
   Artist's illustration of a supermassive black hole at the center of a galaxy.
   Credits: NASA/JPL-Caltech

3. **22/2/2023**
   High-resolution image of an Earth-size planet in the cool side of the habitable zone of a nearby M dwarf.
   Credits: José A. Caballero, Javier Bollaín (Render Area)

4. **28/2/2023**
   Group picture of the Chinese delegation of eXTP, together with ICE-CSIC researchers and engineers.
   Credits: ICE-CSIC.

5. **1/3/2023**
   On 27 September 2022, DART impacted the Dimorphos asteroid.
   Credits: DART / NASA

6. **14/3/2023**
   This photo shows a three colour composite of the well-known Crab Nebula (also known as Messier 1), as observed with the FORS2 instrument in imaging mode in the morning of November 10, 1999.
   Credits: ESO.

7. **20/4/2023**
   ICE-CSIC members from the Advanced Engineering Unit and the Communication & Outreach office at the MEMEnginy fair.
   Credits: ICE-CSIC.

8. **12/5/2023**
   Artist impression of a black hole accretion.
   Credits: John A. Paice.

9. **17/5/2023**
   Artistic view of the nova RS Oph, composed of a white dwarf that accretes material from a red giant companion star.
   Credits: superbossa.com/MPP.

10. **13/6/2023**
    The Dark Energy Spectroscopic Instrument sits atop the Mayall 4-Meter Telescope at Kitt Peak National Observatory. DESI's early data gathered in 2020 and 2021 is now publicly available.
    Credits: Marilyn Sargent/ Berkeley Lab

11. **29/6/2023**
    A 31.5 solar-mass black hole with an 8.38 solar-mass black hole companion viewed in front of its (computer generated) stellar nursery prior to merging.
    Credits: Aaron M. Geller / Northwestern University CIERA & NUIT-RCS; ESO / S. Brunier.

12. **30/6/2023**
    Illustration of the Euclid space mission in space.
    Credits: ESA/Euclid/Euclid Consortium/NASA. Galaxies in the background: NASA, ESA, and S. Beckwith (STScI) and the HUDF Team.

13. **3/7/2023**
    Francisca Kemper, ICREA researcher at ICE-CSIC and IEEC, chair of the 6th Summer School of the Institute of Space Sciences.
    Credits: ICE-CSIC.

14. **19/7/2023**
    An artist's impression of the ultra-long period magnetar.
    Credits: ICRAR.

15. **28/7/2023**
    Group picture first ARRAKIHS Consortium meeting.
    Credits: ICE-CSIC.

16. **31/7/2023**
    The image on the left was taken by Euclid's VISible instrument (VIS) and the image on the right was taken by Euclid´s Near-Infrared Spectrometer and Photometer (NISP).
    Credits: ESA/Euclid/Euclid Consortium/NASA, CC BY-SA 3.0 IGO.

17. **30/8/2023**
    Artist's impression of the pulsar PSR J1023+0038.
    Credits: ESO/M. Kornmesser.

18. **8/9/2023**
    Diego F. Torres, ICE-CSIC researcher and director from 2016 to 2023.
    Credits: Departament de Recerca i Universitats, Generalitat de Catalunya.

19. **18/9/2023**
    Spacecraft Visualisation of the Nancy Grace Roman Space Telescope.
    Credits: GSFC/SVS.

20. **4/10/2023**
    The Euclid IST:NL team at the Institute of Space Sciences.
    Credit: ICE-CSIC.

21. **5/10/2023**
    Scientists involved in the Spanish contribution to LISA.
    Credits: ICE-CSIC.

22. **11/10/2023**
PRETTY is testing 'slant' reflectometry.
Credits: ESA.

23. **7/11/2023**
Spiral Galaxy IC 342.
Credits: ESA/Euclid/Euclid Consortium/NASA, image processing by J.-C. Cuillandre (CEA Paris-Saclay), G. Anselmi; CC BY-SA 3.0 IGO.

24. **15/11/2023**
Artist's concept of one of the brightest explosions ever seen in space: a Luminous Fast Blue Optical Transient (LFBOT).
Credits: NASA, ESA, NSF's NOIRLab, Mark Garlick, Mahdi Zamani.

25. **23/11/2023**
The Euclid Cosmological Simulations SWG team.
Credits: ICE-CSIC.

26. **29/11/2023**
Tracing a link between two neighbour planets at regular time interval along their orbits, creates a pattern unique to each couple. The six planets of the HD110067 system create together a mesmerising geometric pattern due to their resonance-chain.
Credits: Thibaut Roger (NCCR PlanetS).

27. **14/12/2023**
Detection of FH1 next to the northern lights.
Credits: Eloy Peña-Asensio et al.

28. **18/12/2023**
SEM image of the very first genuine ICE-CSIC space rock.
Credits: Jon Larsen.

INSTITUTE OF SPACE SCIENCES

Annual Report 2023

Institute of Space Sciences

EXCELENCIA MARÍA DE MAEZTU

CSIC

IEEC